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Visual Word Recognition by Arab ESL Learners: Phonological Versus Orthographic Consonantal Influence on Vowels

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Abstract

The current study is on second language acquisition (SLA), and the focus is on the process of visual word recognition in English by Arab learners of English as a second language (ESL). Arab ESL learners have poor performance in their visual word recognition in English, which has been explicated in terms of their poor spelling knowledge of English words. The goal of the current study was to show that Arab ESL learners' visual word recognition in English is also influenced by properties of English influencing American English (AE) native speakers' visual word recognition.

In chapter 3, it is hypothesized that, in addition to the influence of grapheme-phoneme correspondence (GPC) rules (yielding the regular vowels), AE native speakers' vowel accuracy is influenced by two distinct sources (both yielding a conditioned vowel): phonological properties of English (i.e. constraints), and orthographic properties of English (i.e. regularity and consistency). Looking into the effect of the lack of consistency, this effect was obtained with orthographic but not phonological properties in the analysis of AE native speakers' accuracy and latency with nonwords in the lexical decision task (LDT) in the English Lexicon Project (ELP), a large online database. The investigation of AE native speakers' visual word recognition aimed to assess Arab ESL learners' performance in terms of the same phonology-orthography distinction.

In chapter 4, nonword naming data was collected from 44 Arab ESL learners (from Saudi Arabia), divided into low and high proficiency groups (n = 22 in each). Based on the proportion of the conditioned vowel, the distinction between strong and weak phonological constraints was supported, and the orthographic consistency effect was obtained while the orthographic regularity effect was not. A post hoc analysis shows that there was also an overall increase in the proportion of the regular vowel (reflecting the increasing influence of GPC rules), and an across-the-board decrease in the proportion of vowels not used in English words. More broadly, support is obtained for the distinction between phonological and orthographic properties (both yielding the conditioned vowel), the influence of both of which is different from that of GPC rules (yielding the regular vowel).

These findings do not challenge the explanation ascribing Arab ESL learners' poor visual word recognition performance to their poor *explicit* spelling knowledge; instead, they show that their accuracy in this process is also influenced by L2 exposure resulting in increasing *implicit* knowledge of English grapheme-phoneme correspondences as well as the irregularities and inconsistencies therein.

Keywords: visual word recognition, SLA, ESL, Arabic, vowels, phonology, orthography, constraints, regularity, consistency

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List of Abbreviations

AE .... American English

ANOVA .... analysis of variance

body-N .... body-Neighborhood

ELP .... English Lexicon Project

ESL .... English as a second language

F1 .... first formant

HF .... high-frequency

L1 .... first language

L2 .... second language

LF .... low-frequency

ms .... millisecond

N .... neighborhood

NRA .... no regular analogy

NRA-Many .... no regular analogy-many

NRA-Unique .... no regular analogy-unique

ns .... not significant

RM .... repeated measure

RT .... response time

SD .... standard deviation

Chapter 1: Introduction

The current study was conducted to obtain a better understanding of visual word recognition, a lower-level process during silent reading whereby visual letter strings (input) are recognized by matching them to words in the mental lexicon (orthographic, phonological, and semantic representations) (output) (Perfetti, 1984; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). This lower-level process is of great importance in silent reading (Perfetti, 1984), especially as higher-level processes (e.g. integrating context) rely on the efficiency of and the output of lower-level processes (Rayner et al., 2001). The focus is on visual word recognition by learners of English as a second language (ESL), specifically Arab ESL learners.

Within the field of second language acquisition (SLA), the study of visual word recognition by learners of a second language (L2) falls under the domain of the cognitive theory (contrasted with the linguistic theory) of L2 acquisition emphasizing the L2 learner's mental factors (R. Ellis, 1994). The cognitive theory of L2 acquisition has recently attracted a great deal of interest in the field of SLA (VanPatten & Benati, 2010). More specifically, N. Ellis (1999) states that there has been a shift from studying mental *representations* of L2 knowledge to studying the emergence and development of the mental *processes* underlying this knowledge. Focusing on the specific process of visual word recognition (defined above) by Arab ESL learners, the current study looked into this process and its development – both investigated in terms of L2 influences.

1.1. Statement of the Problem

Compared to non-Arab ESL learners, Arab ESL learners have poor performance in their ESL visual word recognition (Fender, 2003; 2008; Hayes-Harb, 2006; Ryan & Meara, 1991). This poor performance has been explained in terms of the transfer of visual word recognition strategies from the first language (L1) (Hayes-Harb, 2006; Ryan & Meara, 1991), as well as the poor spelling knowledge of the L2 (Fender, 2003; 2008). These two explanations, however, do not look into the factors influencing American English (AE) native speakers' accuracy in visual word recognition – hence the area of investigation in the current study.

1.2. Purpose and Significance

The goals of the study are two-fold: (1) to determine the phonological and orthographic factors influencing AE native speakers' vowel accuracy in visual word recognition; and, (2) to find out: (a) whether these two types of factors influence Arab ESL learners' vowel accuracy in visual word recognition, and (b) whether this influence changes across proficiency levels. The significance of the study lies in the proposed phonology-orthography distinction.

1.3. Research Questions

There are two research questions, for AE native speakers and Arab ESL learners, respectively:

1. Is vowel accuracy in visual word recognition by AE native speakers influenced by phonological and/or orthographic factors of English?

2. Is vowel accuracy in visual word recognition by Arab ESL learners influenced by phonological and/or orthographic factors of English, and does this influence change across proficiency levels?

1.4. Hypotheses

To address the first research question, the following is hypothesized: In addition to the influence of grapheme-phoneme correspondence (GPC) rules, vowel accuracy in visual word recognition by AE native speakers is influenced by two distinct sources: (a) phonological properties of English (i.e. “phonological constraints”), and (b) orthographic properties of English (e.g. consistency and regularity). A *grapheme* is an orthographic unit comprising one or more letters representing a single phoneme. A *GPC rule* reflects the most common spelling-to-sound correspondence between a grapheme and a phoneme. For example, the grapheme <ea> mostly represents the vowel phoneme /i/ in English (e.g. <beach, dream>), hence the GPC rule <ea>→/i/. A *phonological constraint* is a phonological condition stipulating that two (or more) phonemes may not be adjacent (within a syllable). For example, /æ/ does not occur before /ɹ/, stated in the phonological constraint *æɹ. *Regularity* refers to whether or not a grapheme follows a GPC rule. *Consistency* refers to the degree of the consistency of the mapping from letters to sounds, with focus on the *body* (vowel + coda letters). For instance, the body <-eaf> is inconsistent, regular in <leaf> /lif/ (in line with <ea>→/i/) but irregular in <deaf> /dɛf/ (violating <ea>→/i/). The focus is on vowels, as most of the irregularity and inconsistency in English are in vowels.

To address the second research question, the following is hypothesized: In addition to the influence of GPC rules, vowel accuracy in visual word recognition by Arab ESL learners is influenced by two distinct sources: (a) phonological properties of English: phonological constraints, reflecting the strength of a constraint and remaining constant across proficiency levels; and, (b) orthographic properties of English: reflected in the consistency and regularity effects, both increasing across proficiency levels. A phonological constraint may exert a *strong* or a *weak* influence in terms of the prohibition of adjacency between phonemes. The *consistency effect* results from lack of consistency and the *regularity effect* does so from lack of regularity, both yielding less accuracy and/or longer latency (time elapsed from the onset of a stimulus until a response is detected).

1.5. Summary of Methodology

A *nonword* is a string of letters resembling a word (hence the term “pseudoword”), and it is usually pronounceable (e.g. <dage, lin, moff>) (Harley, 2008). Two very common psycholinguistic tasks using nonwords have been used: the *lexical decision task (LDT)*, and *nonword naming*. In the LDT, AE native speakers' accuracy and latency in deciding that nonwords were not real English words was analyzed. The nonword LDT data was collected from a large on-line database: the English Lexicon Project (ELP). In nonword naming, Arab ESL learners' pronunciation of the vowels in isolated visually-presented nonwords was analyzed. The nonword naming data was collected from 44 Arab ESL learners (speaking the Saudi dialect) at English Programs for Internationals (EPI) at the University of South Carolina (USC), Columbia during summer 2014.

1.6. Organization of the Dissertation

The literature review (chapter 2) covers Arab ESL learners' ESL visual word recognition and their ESL vowel production, as well as AE native speakers' visual word recognition and their processing of consonants and vowels. In chapters 3 and 4, visual word recognition is studied with AE native speakers and Arab ESL learners, respectively. In chapter 5, there is a general discussion, limitations, and the conclusion.

Chapter 2: Literature Review

There are four sections in this chapter, respectively looking into: (a) Arab ESL learners' visual word recognition, (b) Arab ESL learners' accuracy in producing AE vowels, (c) an overview of the study of visual word recognition, and (d) processing consonants and vowels in English. The first two sections focus on Arab ESL learners, while the last two do so on AE native speakers.

2.1. Arab ESL Learners' Visual Word Recognition

Compared to non-Arab ESL learners, there is evidence that Arab ESL learners have poor performance in their ESL visual word recognition (Fender, 2003; Hayes-Harb, 2006; Ryan & Meara, 1991). The explanations for this poor performance and difficulty in visual word recognition consider the role of transfer, learning strategies, and spelling knowledge. More specifically, the poor performance has been attributed to: (a) negative L1 transfer of the strategy of focusing on consonant letters at the expense of vowel letters (Ryan & Meara, 1991; Hayes-Harb, 2006), and (b) poor L2 spelling knowledge (Fender, 2008) resulting in poor visual word recognition (Fender, 2003) and hence poor silent reading (Fender, 2008). These two accounts are evaluated in the following four sections: (a) visual word recognition in Arabic, (b) the negative L1 transfer explanation, (c) the poor L2 spelling knowledge explanation, and (d) cross-linguistic comparisons between ESL learners' L1s in three respects: writing systems (alphabetic vs. non-alphabetic), alphabets (Roman vs. non-Roman), and orthographic depth (deep vs. shallow).

2.1.1. Visual word recognition in Arabic. The vowel information in the Arabic script is underrepresented in two respects: (a) the lack of letters representing short vowels, and, (b) the non-use of diacritics (meant to represent short vowels). Regarding the former respect, of the 28 letters in the Arabic alphabet, 25 letters represent consonant sounds and only three represent long vowel sounds (i.e. the syllable-medial /a:/, /i:/ and /u:/ corresponding to the syllable-initial glide plus long vowel sequences /ʔa:/, /ji:/ and /wu:/, respectively). Given this underrepresentation of vowel sounds, Arabic has been described as having a “consonantal script” (Harley, 2008). Concerning the latter respect, although vowel information can be indicated by diacritics (thus rendering a “vowelized script”), most printed media do away with diacritics and use an unvowelized script instead. Roman & Pavard (1987) conducted an eye movement study and found that diacritics slow down reading and may thus be considered to be perceptual noise. Arabic readers utilize two strategies to help them determine the vowel sounds in words during visual word recognition: (a) making use of diacritics (when available), and (b) relying on the semantic and syntactic context (Abu-Rabia, 1997; 1999).

2.1.2. The negative L1 transfer explanation. Arab ESL learners' difficulty in processing English vowel letters in visual word recognition has been recognized in two studies (Ryan & Meara, 1991; Hayes-Harb, 2006), both suggesting the transfer of the strategy of focusing on consonant letters. This transfer, however, may have little empirical support.

Ryan & Meara (1991) used the identity judgment task in which participants briefly see an English word (e.g. <department>) and then decide whether the second word they see has the same spelling (identical condition, e.g.

<department>) or a different one (deleted vowel condition, e.g. <dpartment>). Arab ESL learners were slower and less accurate (2,916 millisecond (ms) latency; 17.23% errors) in recognizing a deleted vowel than non-Arab ESL learners (1,815 ms latency; 5.25% errors), while a control group of AE native speakers was the fastest and most accurate of the three groups (1,381 ms latency; 0.8% errors).

Hayes-Harb (2006, Experiment 1) replicated the study by Ryan & Meara (1991) using the same task with a third condition: deleted consonant condition (e.g. <deparment>). No significant difference in errors, however, was obtained between the three groups (Arab, non-Arab, control) or within a group in the three conditions (identical, deleted vowel, deleted consonant). Hayes-Harb (2006) states that the lack of difference within a group in the three conditions casts doubts on the ability of this task to tap differences in processing vowel letters vis-à-vis consonant letters (with the three groups). However, the Arab group's latency in the three conditions (identical: 1,223 ms; deleted vowel: 1,055 ms; deleted consonant: 1,121 ms) was significantly longer than that of the non-Arab group (999 ms, 882 ms, 916 ms), while the latency of the control group was significantly the shortest of the three (886 ms; 731 ms; 763 ms). Longer processing time may account for the Arab group's similar accuracy with the two other groups, an issue not addressed by the researcher.

As an alternative, Hayes-Harb (2006, Experiment 2) used the letter detection task in which participants are asked to circle the vowel letter <o> and consonant letter <t> (both being very frequent letters in English) while reading for comprehension. Each participant was given four short passages, two in which to circle <o> and the other two to circle <t>. Participants were allotted 50 seconds per passage, and were then asked some comprehension questions. The researcher found that the Arab group had about the same accuracy with <o> (70% of this letter in the two passages was circled) and <t> (71%), while the non-Arab group had a higher accuracy with <o> (93%) than <t> (81%), as did the control group (<o> 86% and <t> 76%). It is argued that, owing to the underrepresentation of vowel information in the Arabic script, Arab ESL learners do not pay more attention to vowel than consonant letters as the non-Arab group and the control group do. Hayes-Harb (2006) states: “Arabic speakers transfer visual word processing *strategies* concerning the allotment of attention to vowel and consonant letters from Arabic to reading English” (p. 335, emphasis added). There are, however, a number of issues with this conclusion. For one, the transfer of the strategy of focusing on consonant letters would have, in theory, resulted in higher accuracy in circling consonants than vowels. Arab ESL learners, however, had the same low accuracy with both vowels and consonants (<o> 70%; <t> 71%). Importantly, the non-Arab group clearly outperformed the AE native speaker control group in circling both the letter <o> (93% vs. 86%) and <t> (81% vs. 76%), an outcome which arguably compromises the findings.

In light of the above, the explanation for Arab ESL learners' poor performance in visual word recognition in terms of the negative L1 transfer of the strategy of focusing on consonant letters may need more empirical support. Importantly, while the findings of the letter detection task may be compromised, those of the identity judgment task (Ryan & Meara, 1991) have been attributed to a second explanation: poor spelling knowledge (Fender, 2008), as outlined next.

2.1.3. The poor L2 spelling knowledge explanation. Unlike the explanation in terms of the negative L1 transfer of the strategy of focusing on consonant letters, the poor L2 spelling knowledge explanation – put forth by Fender (2003; 2008) – has clear empirical support. Fender (2008) claims that poor spelling knowledge in English is the main cause of Arab ESL learners' relatively poor performance in ESL visual word recognition (Fender, 2003; Ryan & Meara, 1991) as well as in silent reading in ESL (Fender, 2008).

Using the lexical decision task (LDT) (wherein a participant has to decide whether a string of letters is a word or not, e.g. <like, week> vs. <gank, kisp>), Fender (2003, Experiment 1) found that Arab ESL learners were significantly slower (1,030 ms latency) and less accurate (73% accuracy) than Japanese ESL learners of equal proficiency (785 ms latency; 86% accuracy), while an English control group was the fastest and most accurate (658 ms latency; 95% accuracy). Fender (2003) describes Arab ESL learners as having “less developed and less fluent English word recognition skills” (p. 305).

Furthermore, Fender (2008) compared the performance of an Arab ESL group with a proficiency-matched non-Arab ESL group in three tests: listening, reading, and spelling. The listening and reading tests were taken from a TOEFL test, while the spelling test consisted of the dictation of 58 words comprising three types of spellings with increasing difficulty: (a) within-word spellings (e.g. <catch>, 22 items), (b) syllable juncture spellings (e.g. <music>, 18 items), and (c) derivational spellings (e.g. <recognize>, 18 items). Although the Arab group slightly outperformed the non-Arab group in the listening test (56% vs. 51%), the non-Arab group greatly outperformed the Arab group in both the reading test (59% vs. 42%) and the spelling test in all three types of spellings: within-word (94% vs. 83%), syllable juncture (81% vs. 56%), and derivational (81% vs. 47%). Fender (2008) argues that Arab ESL learners' difficulty in visual word recognition (and in silent reading) stems mainly from their poor spelling knowledge, which was evident in their low scores in the spelling test in all three different types of spellings [1].

Fender (2008) states that there is a strong relation between spelling knowledge and visual word recognition, as the development of spelling knowledge leads to more efficient and more accurate visual word recognition in children whose native language is English (Ehri, 2005; Perfetti, 1992, 1997; Perfetti & Hart, 2001) as well as ESL children (Chiappe, Glaeser, & Ferko, 2007; Geva & Zadeh, 2006; Wade-Woolley & Siegel, 1997). Based on the above, Fender (2008) argues that the results of the LDT in Fender (2003, Experiment 1) as well as those of the identity judgment task in Ryan & Meara's (1991) study reflect Arab ESL learners' poor spelling knowledge [2]. Therefore, poor L2 spelling knowledge is the main cause of Arab ESL learners' difficulty in processing AE vowel letters in visual word recognition (Fender, 2008).

2.1.4. Cross-linguistic comparisons between L1s. The support for the L2 poor spelling knowledge explanation notwithstanding, the influence of L1 transfer on L2 visual word recognition is below discussed in light of three types of cross-linguistic comparisons: type of writing system (alphabetic vs. non-alphabetic), type of alphabet (Roman vs. non-Roman), and depth of orthography (deep vs. shallow). The three perspectives are not directly relevant to the current study wherein the focus is on L2 rather than L1 factors.

1 Fender (2008) also suggests that Arab ESL learners may exert greater reliance on context to aid visual word recognition, an argument tentatively supported by the lack of correlation (r = -.15, not significant (ns)) between the Arab group's spelling and reading tests, while the correlation between the two tests for the non-Arab group was strong and significant (r = .57).

2 Fender (2008) entertains a few explanations for this poor spelling knowledge, e.g. English education programs in schools back home, and limited reading experience in the L2. For further explanation of the causes of this poor spelling knowledge, see Saigh & Schmidt (2012).

2.1.4.1. Alphabetic vs. non-alphabetic L1 writing systems. Fender (2008) states that ESL learners whose L1 has an alphabetic script (e.g. Arabic) use "more efficient phonological decoding skills", while those whose L1 has a non-alphabetic (i.e. logographic) script (e.g. Chinese) use "more efficient ESL visual-orthographic processing skills" (p. 24). Fender (2008) states that the latter skills are more important for ESL visual word recognition (and hence reading), and he cites a study by Nassaji (2003) showing that the L2 reading proficiency of advanced-level Persian-speaking ESL learners depended more on "the use of visual orthographic information" than on "phonological decoding processes and phonetic codes during word recognition" (Fender, 2008, pp. 20-21).

There is a large amount of support for the argument that ESL learners with a non-alphabetic L1 (e.g. Chinese, Japanese) rely more on orthographic processing (Akamatsu, 1999; 2003; Gairns, 1992; Wang, Koda, & Perfetti, 2003), while ESL learners with an alphabetic L1 (e.g. Arabic, Persian, Spanish, Korean) rely more on phonological processing (Gairns, 1992; Koda, 1995; Wang et al., 2003; Wang & Koda, 2007). Thus, Arab ESL learners depend relatively more on phonological than orthographic processing, which may be less advantageous when it comes to improving one's ESL visual word recognition skills.

2.1.4.2. Roman vs. non-Roman L1 alphabets. Fender (2008) states that ESL learners whose L1 uses the Roman alphabet "transfer not only familiarity with letters but also corresponding letter-sound mapping patterns" (p. 25) (see Muljani, Koda, & Moates, 1998) [3]. Since the Arabic alphabet is used in Arabic, Arab ESL learners do not have the advantage of letter familiarity.

3 However, differences in the correspondences between letters and sounds in the two languages can cause interference in L2 auditory perception, as has been shown for Dutch-speaking ESL learners in their perception of the English /ɛ–æ/ contrast, mainly perceiving both vowels as /ɛ/ (Escudero, Hayes-Harb, & Mitterer, 2008; Escudero & Wanrooij, 2010).

2.1.4.3. Deep vs. shallow L1 orthographies. According to the Orthographic Depth Hypothesis (e.g. Frost, Katz, & Bentin, 1987; Katz & Frost, 1992), based on the (feedforward) consistency of the mappings from letters to sounds, an orthography may be described as lying along a continuum of orthographic depth, at one extreme of which are shallow/transparent orthographies (a very high or perfect consistency, e.g. Serbo-Croatian, Spanish) and at the other are deep/opaque ones (a low consistency, e.g. Hebrew, Irish).

Although vowelized Arabic script is shallow (high consistency), most written Arabic – owing to the non-use of diacritics – is unvowelized (low consistency) and Arabic may thus be considered to have a deep orthography (Stein, 2010). English orthography, on the other hand, is quite deep (low consistency) (Katz & Frost, 1992).

To test the influence of L1 orthographic depth on L2 processing, Erdener & Burnham (2005) compared the nonword repetition accuracy of four groups: (a) Turkish (transparent, T) learners of Spanish (T) (T→T), (b) Turkish (T) learners of Irish (O) (T→O), (c) Australian English (O) learners of Spanish (T) (O→T), and (d) Australian English (O) learners of Irish (O) (O→O). The nonwords were presented through three media: auditory (A), visual (V) (i.e. seeing a video of somebody uttering the nonword), and orthographic (O). There were four conditions: auditory only (A); auditory and visual (AV); auditory and orthographic (AO); and, auditory, visual, and orthographic (AVO). Only the findings of the AO and AVO media (i.e. the “orthographic condition”, according to the researchers) are discussed here. It was found that: (a) As expected, Turkish speakers learning Spanish (T→T) had a much higher accuracy than Turkish speakers learning Irish (T→O), and (b) Importantly, there were no significant differences between

Australian English speakers learning Spanish (O→T) and Australian English speakers learning Irish (O→O). These findings suggest that L2 learners with a shallow/transparent L1 (e.g. Turkish) have greater sensitivity to the depth of the L2, i.e. greater ease when the L2 is shallow/transparent (e.g. Spanish) but greater difficulty when the L2 is deep/opaque (e.g. Irish). Erdener & Burnham (2005) conclude that: “Turkish participants are affected by orthographic information more than their Australian counterparts” (p. 218).

This finding from Erdener & Burnham's (2005) study suggests that the depth of the L1 was crucial. Tentatively, since both Arabic (when unvowelized, as it usually is) and English are quite deep/opaque, Arab ESL learners may not have the sensitivity to English orthographic forms that ESL learners with a shallow/transparent L1 do, an issue for further study.

2.1.5. Summary. Regarding visual word recognition in Arabic, vowel information is underrepresented in the Arabic script in two respects: (a) the small number of vowel letters, and (b) the non-use of diacritics (thus rendering an unvowelized script). Arabic readers adopt two strategies in their visual word recognition in Arabic: (a) making use of diacritics (when available), and (b) relying on the semantic and syntactic context (section 2.1.1). The attribution of Arab ESL learners' difficulty in processing English vowel letters during visual word recognition to the transfer of the strategy of focusing on consonant letters has little empirical support (section 2.1.2). On the other hand, there is strong support for the explanation in terms of poor spelling knowledge, which results in poor visual word recognition skills and hence poor reading skills (section 2.1.3).

Moreover, in terms of transfer stemming from orthographic differences between the L1 and the L2, it is argued that: (a) Arab ESL learners do not have the advantage of focusing on orthographic processing (vis-à-vis ESL learners with a non-alphabetic L1) (section 2.1.4.1), and (b) they do not have the familiarity with the Roman alphabet (vis-à-vis ESL learners with a Roman-alphabet L1) (section 2.1.4.2). Additionally, a tentative claim is made that Arab ESL learners may not have the sensitivity to the depth of the English orthography (vis-à-vis ESL learners with a shallow/transparent L1), as both Arabic and English are deep/opaque (section 2.1.4.3).

Overall, although Arab ESL learners' poor ESL visual word recognition reflects their poor L2 spelling knowledge, L1 transfer may have a role in terms of: (a) Arab ESL learners' focusing on phonological rather than orthographic processing – the latter being more advantageous (negative transfer), and (b) Arab ESL learners' having a different L1 alphabet (lack of positive transfer), but (c) perhaps not Arab ESL learners' having a deep L1 orthography.

2.2. Arab ESL Learners' Accuracy in Producing AE Vowels

Most of the irregularity in English are in the spelling-to-sound correspondences of vowels rather than consonants (Andrews & Scarratt, 1998; Berent & Perfetti, 1995; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995; Venezky, 1970; Zevin & Seidenberg, 2006). Given this, L1 phonological transfer influencing L2 vowel production may be taken into account when studying L2 learners' visual word recognition accuracy when the collected data is phonological, as in the nonword naming task used in the current study (chapter 4). This perspective may shed light or qualify a finding, perhaps supporting or discounting an explanation of an observed pattern (see section 4.6, footnote 44). There are two parts: (a) a comparison between the vowels in AE and in Arabic, and (b) Arab ESL learners' low accuracy in producing AE vowel phonemes.

2.2.1. Comparison between the vowels in AE and in Arabic. In standard AE, there are: (a) twelve vowels (front /i, ɪ, e, ɛ, æ/, back /u, ʊ, o, ɔ, ɑ, ʌ/, and central /ɚ/), and (b) three diphthongs /aɪ, aʊ, ɔɪ/ (Hammond, 1997; 1999) [4]. A syllable-final /ɹ/ influences the preceding vowel. That is, syllable-final /ɹ/ occurs after only five vowels in English: (a) the tense vowel /ɑ/ (/ɑɹ/) (e.g. <car>), and (b) the four tense vowels /i, e, u, o/ and it results in the preceding vowel becoming lax and slightly shorter (/ɪɹ, ɛɹ, ʊɹ, ɔɹ/) (e.g. <beer, hair, tour, more>) (Veatch, 1991; Wells, 1982) [5]. Below are the AE vowel phonemes:

Table 2.1. AE vowel phonemes

	Front	Central	Back	
			Unrounded	Rounded
High	i ɪ iɹ / ɪɹ			u ʊ uɹ / ʊɹ
Mid	e ɛ eɹ / ɛɹ	ɚ	ʌ	o ɔ oɹ / ɔɹ
Low	æ		ɑ ɑɹ	

Concerning Arabic, on the other hand, a distinction is made between Classical Arabic (the language of the Holy Quran), Modern Standard Arabic (the normative language used in the media), and Colloquial Arabic dialects (the everyday spoken vernacular) (Newman, 2002). In addition to the colloquial dialect, most Arabic speakers can use Modern Standard Arabic (Newman, 2002).

Modern Standard Arabic has six vowels (or three pairs differing in length): close front /i:, i/, close back /u:, u/, and open /a:, a/ (Al-Ani, 1970; Kopczynski &

4 The reduced vowel schwa allophone [ə] may replace other vowels in unstressed syllables, mostly in polysyllabic words.
5 Vowel shortening before /ɹ/ is a recent sound change in AE (Kessler & Treiman, 2001).

Meliani, 1993; Mitchell, 1990, 1993). Most Colloquial Arabic dialects additionally have the long vowels /e:/ and /o:/, neither of which has a short counterpart (*/e/ and */o/) (Mitchell, 1993). Arabic dialects having these eight vowels (i.e. long /i:, e:, u:, o:, a:/ and short /i, u, a/) include Egyptian Arabic (Mitchell, 1990; 1993), Algerian Arabic (Kopczynski & Meliani, 1993), and Saudi Arabic (Prochazka, 1988) as well as other dialects in the Persian Gulf states (henceforth Gulf Arabic) (Holes, 1990). Mitchell (1990) states that the vowels /e:/ and /o:/ are reflexes of Classical Arabic vowel + consonant combinations /ay/ and /aw/. Mitchell (1993) adds that there are, however, contexts in which /ay/ and /aw/ can not be replaced by /e:/ and /o:/, such as proper names (e.g. /layla/, a female name), formal words (e.g. /θawra/ “revolution”), and morphologically complex words (e.g. /maw'lu:d/ “new-born baby”).

Additionally, some consonants change the pronunciation of certain vowels when they occur in a neighboring position. These consonants (stops and fricatives) are highlighted in the table below comprising all the consonants in Standard Arabic:

Table 2.2. Standard Arabic consonants (adapted from Al-Ani, 1970)

Manner	Bi-labial	Labio-dental	Inter-dental	Alveo-lar	Alveo-palatal	Pala-tal	Ve-lar	Uvu-lar	Phary-yngeal	Glo-ttal
Stops	b			t tˤ d dˤ			k g	q		ʔ
Fricatives		f	θ ð ðˤ	s sˤ z	ʃ ʒ		x ɣ		ħ ʕ	h
Nasals	m			n						
Liquids				l, r						
Glides						j	w			

The highlighted consonants above fall under two groups: (a) emphatics: stops /tˤ, dˤ/, fricatives /sˤ, ðˤ/ [6], and (b) velar and postvelar consonants: stops /k, g, q, ʔ/, fricatives /x, ɣ, ħ, ʕ/ (Al-Ani, 1970; Mitchell, 1990; 1993).

The focus below is on Gulf Arabic, as the Arab participants whose data was collected and analyzed in chapter 4 were all from Saudi Arabia. Holes (1990) recognizes the following vowel allophones in Gulf Arabic that are determined by their environment (adjacency to an emphatic or a velar or postvelar consonant, being in an unstressed or a word-final position):

Table 2.3. Gulf Arabic vowel allophones conditioned by neighboring consonant phonemes (Holes, 1990)

Phonemes	Allophones	Examples	Environment
iː	iː	[dæliːl] "guide"	default [7]
	əiː iːə	[tˤəiːn] "mud" [tɪħiːədˤ] "she menstruates"	emphatics
eː	eː	[keːf] "how"	default
	əeː eːə	[sˤəeːf] "summer" [xeːətˤ] "thread"	emphatics
i	ɪ	[bɪnt] "girl"	default
	ə	/tˤəbb/ "medicine"	emphatics
	ə	[kətæːb] "book"	unstressed
	i	[bɪnti] "my daughter"	word-finally
uː	ʊː	[agʊːl] "I say"	default
oː	oː	[noːʕ] "sort"	default
u	ʊ	[ħʊbb] "love"	default
	ə	[sərʊːr] "happiness"	unstressed
	u	[bædu] "Bedouin"	word-finally

6 Emphatics are also called pharyngealized consonants and velarized consonants. They are produced with a laryngopharyngeal constriction, a raising of the larynx, and a raising of the back of the tongue with a concomitant lowering of the front of the tongue (Jakobson, 1957; Kopczynski & Meliani, 1993).

7 Conventionally, the same phoneme symbol is used to represent its default allophone (e.g. /e/-[e]). This convention is violated in many instances in the Tables 2.3 and 2.4 (i.e. /i/-[ɪ], /uː/-[ʊ], /u/-[ʊ], /a/-[æ], /a/-[æ]). The symbols for phonemes and allophones are reported as they are used in the source, Holes (1990).

a:	æ:	[ʃæ:bb] "youth"	default
	a:	[xa:li] "empty"	velar & postvelar
	ɒ:	[sˤɒ:m] "he fasted"	emphatics
	æ	[ɣadæ] "lunch"	word-finally
a	æ	[bædu] "Bedouin"	default
	a	[baʕad] "after"	velar & postvelar
	ɒ	[sˤɒff] "row"	emphatics

/i:/ is [i:] by default (e.g. [dæli:l] "guide"), and it has an on-glide after an emphatic (e.g. [tˤəi:n] "mud") and an off-glide before an emphatic (e.g. [tɪħi:ədˤ] "she menstruates"). Similarly, /e:/ is [e:] by default (e.g. [ke:f] "how"), and it has an on-glide after an emphatic (e.g. [sˤəe:f] "summer") and an off-glide before an emphatic (e.g. [xe:ətˤ] "thread"). /i/ is [ɪ] by default (e.g. [bɪnt] "girl"), [ə] when contiguous to an emphatic (e.g. /tˤəbb/ "medicine") or when in an unstressed syllable (e.g. [kətæ:b] "book"), and [i] word-finally (e.g. [bɪnti] "my daughter"). /u:/ is always [ʊ:] (e.g. [agʊ:l] "I say"). Similarly, /o:/ is always [o:] (e.g. [no:ʕ] "sort"). /u/ is [ʊ] by default (e.g. [ħʊbb] "love"), [ə] when in an unstressed syllable (e.g. [sərʊ:r] "happiness"), and [u] word-finally (e.g. [bædu] "Bedouin"). /a:/ and /a/ have the same three pairs of allophones, differing only in length: fronted [æ:, æ] by default (e.g. [ʃæ:bb] "youth", [bædu] "Bedouin"), central [a:, a] when contiguous to a velar or postvelar consonant (e.g. [xa:li] "empty", [baʕad] "after"), and retracted and rounded [ɒ:, ɒ] when contiguous to an emphatic (e.g. [sˤɒ:m] "he fasted", [sˤɒff] "row"). Additionally, the default allophone [æ:] is shortened word-finally to [æ] (e.g. [ɣadæ] "lunch", in contrast with [ɣadæ:k] "your lunch").

Two vowel allophones may be added: [ɑ:] and [ʌ]. /a:/ is realized as the allophone [ɑ:] before /r/ (e.g. /nɑ:r/ "fire") (Mitchell, 1990). /a/ may be reduced in informal speech to [ʌ]: (a) when contiguous to a velar or postvelar consonant (e.g. [xad]→[xʌd] “cheek”), (b) when contiguous to an emphatic (e.g. [bɒtˤ]→[bʌtˤ] “ducks”), and (c) before /r/ (e.g. [bɒr]→[bʌr] “land, open country”) (Mitchell, 1990).

Gulf Arabic thus has the following vowel phonemes and allophones (the default allophones are highlighted):

Table 2.4. Vowels in Gulf Arabic (Holes, 1990; Mitchell, 1990)

Phonemes

	Front	Central	Back
High	i: – i		u: – u
Mid	e:		o:
Low		a: – a	

Allophones

	Front	Central	Back
High	**i:** əi:/i:ə – **ɪ** i		**ʊ:** – **ʊ** u
Mid	**e:** əe:/e:ə		**o:**
Low	**æ: – æ**	a: – a	ɒ: – ɒ

The table on the left below has the 12 AE vowel phonemes, and the one on the right has the eight Gulf Arabic vowel phonemes plus the three allophones [æ:, ɑ:, ʌ] in brackets:

Table 2.5. Vowel phonemes in AE and Gulf Arabic

AE

	Front	Central	Back	
			Un-round	Round
High	i ɪ			u ʊ
Mid	e **ɛ**	**ɚ**	**ʌ**	o **ɔ**
Low	**æ**		**ɑ**	

Gulf Arabic

	Front	Central	Back	
			Un-round	Round
High	i: – i			u: – u
Mid	e:		[ʌ]	o:
Low	[æ:]	a: – a	[ɑ:]	

The six unhighlighted AE vowels (front /i, ɪ, e/ and back /u, ʊ, o/) have very similar counterparts in Gulf Arabic (front /i:, i, e:/ and back /u:, u, o:/, respectively). Although similar in terms of their general position, the similar vowels are not necessarily identical. For instance, Mitchell (1990) states that the Gulf Arabic high vowels /i:, u:/ and /i, u/ are higher than their AE counterparts /i, u/ and /ɪ, ʊ/, respectively. Additionally, AE tense vowel phonemes /i, e, u, o/ undergo diphthongization, thus showing a vowel movement. They are transcribed as the allophones /iʲ, eʲ, uʷ, oʷ/, respectively. These four AE vowels are more different phonetically than phonemically from their Arabic counterparts.

Of the six highlighted AE vowels, AE phonemes /æ, ʌ/ are similar to the Gulf Arabic allophones [æ:, ʌ]. (As stated above, [æ:] is the default allophone of /a:/, while [ʌ] is a reduced informal variant of /a/.) The Arabic allophone [ɑ:] is different from the AE phoneme /ɑ/ in that Arabic /ɑ:/ only occurs before a coda /r/, while AE /ɑ/ occurs before a coda /ɹ/ as well as elsewhere. Thus, taking into account the Arabic allophones [æ:, ʌ], of the six highlighted AE vowel phonemes /æ, ʌ, ɛ, ɑ, ɚ, ɔ/ in the table above (none of which has a similar vowel phoneme in Arabic), only /ɛ, ɑ, ɚ, ɔ/ have no similar vowel sound in Arabic.

More broadly, in addition to differences in their position, AE vowels are contrasted by tenseness (i.e. /i–ɪ/, /e–ɛ/, /u–ʊ/) and roundedness (i.e. unrounded /ʌ/ and /ɑ/ versus the remaining rounded back vowels). On the other hand, besides differences in their position, Arabic vowels are contrasted only by length (i.e. /i:–i/, /u:–u/, and /a:–a/), while tenseness is peripheral and roundedness is redundant (Kopczynski & Meliani, 1993).

2.2.2. Arab ESL learners' low accuracy in producing AE vowel phonemes. Of the four AE vowel phonemes /ɛ, ɑ, ɚ, ɔ/ which have no similar vowel sound in Arabic, three are produced with low accuracy by Arab ESL learners: (a) /ɛ/, for it has a lower first formant (F1) frequency (Munro, 1993) and it is produced as /ɪ/ (Hubais & Pillai, 2010; Munro, 1993); (b) /ɑ/, as it has a lower F1 frequency and a shorter duration than /o/ and /u/ (Munro, 1993); and (c) /ɚ/, which is fronted as /ɛɹ/ (Hubais & Pillai, 2010). AE vowel /ɔ/ has been left out of many studies of Arab ESL learners' vowel production (e.g. Munro, 1993) [8]. Looking into Omani learners of British English, Hubais & Pillai (2010) consider the vowel /ɔ/ not to be produced with low accuracy. No lack of accuracy has been recognized for: (a) AE /æ/ and /ʌ/, which are similar to the Arabic allophones [æ:] and [ʌ], respectively (Munro, 1993); or, (b) AE vowels /i, ɪ, e, u, ʊ, o/, which are similar to the Arabic phonemes /i:, i, e:, u:, u, o:/, respectively. Hence, absence of a similar vowel sound in Arabic seems to be a necessary but insufficient condition for its low accuracy in production [9].

2.2.3. Summary. The comparison between the vowels in AE and Arabic shows that the AE vowels /ɛ, ɑ, ɚ, ɔ/ have no similar vowel phoneme or allophone in Gulf Arabic (section 2.2.1). Additionally, there is strong evidence of the role of phonological transfer: (a) Of the four AE vowels /ɛ, ɑ, ɚ, ɔ/ (with no similar vowel in Arabic), /ɛ, ɑ, ɚ/ are produced with low accuracy, while no such low accuracy has been recognized for /ɔ/; and (b) No low accuracy has been recognized for AE /æ/ and /ʌ/ (respectively similar to the Arabic allophones /æ:/ and /ʌ/) or for the remaining AE vowels /i, ɪ, e, u, ʊ, o/ (respectively similar to the Arabic /i:, i, e:, u:, u, o:/) (section 2.2.2).

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8 This may be the case because /ɔ/ is absent in many AE dialects, wherein /ɑ/ is used instead (Hammond, 1999).

9 In addition to absence of a similar vowel sound in the L1, there is evidence that the lack of accuracy in producing an AE vowel may be a result of inaccuracy in its perception, as has been documented for the perception of AE /ɛ/ and /ɑ/ by Arab ESL learners (Flege, 1995a,b).

2.3. An Overview of the Study of Visual Word Recognition

Arab ESL learners' accuracy in visual word recognition may be influenced by factors influencing this process by AE native speakers. Five areas of AE native speakers' visual word recognition are reviewed: (a) defining visual word recognition, (b) phonological activation in visual word recognition, (c) skills in phonological vs. orthographic processing, (d) variables influencing visual word recognition, and (e) the effects of the lack of regularity and consistency.

2.3.1. Defining visual word recognition. As stated above, visual word recognition is a process during silent reading whereby visual letter strings (input) are recognized by matching them to words in the mental lexicon (orthographic, phonological, and semantic representations) (output) (Perfetti, 1984; Rayner et al., 2001; for a review, see Balota, Yap, & Cortese, 2006) [10]. Visual word recognition is described by Perfetti (1984) as being "the central recurring event during normal text reading, even in rich contexts" (p. 48), as well as being "the one component unique to reading" (p. 57) and "the heart of reading" (p. 57). Skilled readers have a high efficiency in the lower-level process of visual word recognition and they do not heavily rely on higher-level processes of integrating context to assist them in recognizing visual words, while the reverse is true with poor readers (Perfetti, 1984; Perfetti, Goldman, & Hogaboam, 1979; Rayner et al., 2001; Stanovich, 1980) [11].

10 Perfetti (1984) states that: "the skilled reader has accessible representations of many specific words and a system of implicit rules for word formations. "Word identification" is the process by which visually encoded letters are used to access these representations" (p. 46). Rayner et al. (2001) define efficiency in visual word recognition in terms of automaticity, and they state: "In reading, automaticity entails practice at retrieving word forms and meanings (the output) from printed words (the input)" (p. 40).

11 Rayner et al. (2001) recognize that lack of comprehension during silent reading may result from lower-level processes, and they state: "because the higher levels of processing rely on output from lower levels, an observed problem in text comprehension can also result from lower-level processes, including word identification, basic language processes, and processing limitations" (p. 49).

Greater exposure to and experience with written words results in more efficient visual word recognition skills and better spelling knowledge (Rayner et al., 2001), a finding which has been obtained with child readers (Cunningham & Stanovich, 1991) and adult readers (Cunningham, Stanovich, & Wilson, 1990). There is evidence that the same lexical knowledge of word forms and spelling patterns is used in visual word recognition (decoding) and in spelling out words (encoding) (Burt & Tate, 2002; Ehri, 1997; Holmes & Carruthers, 1998).

Using behavioral data, visual word recognition is usually measured in terms of accuracy and latency. Although there is a number of different tasks that have been used to tap this process (Harley, 2008), two tasks are considered to be the "gold standard" (Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004, p. 284): LDT and naming (see section 1.5 above for simple definitions). Zevin & Seidenberg (2006) describe "word and nonword reading" as "among the most extensively studied areas in cognitive science and neuroscience" (p. 145).

Moreover, the findings from studies of visual word recognition (using tasks such as naming and LDT, among others) frequently generalize to silent reading (Rayner, 1998). In fact, most of what is known about silent reading has come from two lines of research: the study of eye movements in silent reading, and the study of visual word recognition (Rayner et al., 2001).

2.3.2. Phonological activation in visual word recognition. Initially, children learn to read an alphabetic language (e.g. English) by sounding out words (through applying GPC rules, a process termed "phonological recoding", Rayner et al., 2001) and matching them to existing phonological forms (Rayner et al., 2001; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994; Ziegler & Goswami, 2005), hence a role of phonology in learning to read. Skilled readers also have phonological activation in visual word recognition (Rayner et al., 2001), though no “sounding out” of words is necessary (Frost, 1998).

Behavioral data show that there is automatic activation of phonology during visual word recognition even when – importantly – the task used to tap this process does not require producing a phonological output (for a review, see: Berent & Perfetti, 1995; Frost, 1998). Most of this behavioral data focuses on the homophony effect. For example, homophones influence accuracy and latency in the LDT (e.g. <rool> incorrectly considered a word owing to <rule>); (b) homophones affect accuracy in the semantic categorization task (e.g. <rows>, incorrectly categorized as <part of a plant> owing to <rose>); and (c) homophonic primes affect latency in tasks such as naming, LDT, and semantic categorization (e.g. <waist>, homophonic with <waste>, primes <rubbish>).

Additionally, phonological activation has been observed in eye-movement data. For instance, (a) homophones processed parafoveally [12] during reading cause phonological priming (e.g. <beech> priming <beach> more than the similarly-spelled word <bench>) (Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, Sereno, Lesch, & Pollatsek, 1995), and (b) homophones processed parafoveally during reading also cause phonological priming of vowel graphemes (e.g. <dauk> not <daik> priming <dawn>) and of bodies (<raff> not <rall> priming <rack>, for the <a> in <-all> is usually pronounced /ɔ/ as in <call, fall, tall>) (Ashby, Treiman, Kessler, & Rayner, 2006). Moreover, the activation of phonological codes (phonological activation) precedes the activation of meaning (semantic activation) (Folk, 1999; Folk & Morris, 1995).

12 Three areas of human visual perception are recognized: foveal (1 degree from the center of the retina, extending 2 degrees across), parafoveal (surrounding area, 2-10 degrees off-center), and peripheral (further surrounding area, extending 11 degrees and beyond).

2.3.3. Skills in phonological vs. orthographic processing. Different kinds of skills underlie phonological processing and orthographic processing during visual word recognition. This claim has strong empirical support obtained with AE native speakers (Barker, Torgesen, & Wagner, 1992; Cunningham, Perry, & Stanovich, 2001; Cunningham, & Stanovich, 1989; Hagiliassis, Pratt, & Johnston, 2006; Olson, Forsberg, & Wise, 1994; Stanovich & West, 1989; Stanovich, West, & Cunningham, 1991) as well as ESL learners (Bernhardt, 1990; Grabe, 1991; Haynes, & Carr, 1990; Koda, 1994; McLaughlin, 1990; Nassaji & Geva, 1999). According to Hagiliassis et al. (2006), the methodological underpinnings of phonological processing include "phonological recoding" and "phonological awareness" (i.e. awareness of the phonological form of words), while those of orthographic processing include knowledge of the spelling forms of words, knowledge of the spelling patterns in English in general, and/or the application of either or both of these two kinds of knowledge.

2.3.4. Variables influencing visual word recognition. The variables influencing visual word recognition are numerous and they include the following ten: (a) word frequency: An estimate of the number of times a word occurs in a corpus of a million words in (usually) printed materials, hence the word frequency of a word is its token frequency per million; (b) word familiarity: The familiarity of a word based on the familiarity rating assigned to it by native speakers; (c) word semantics: The meaningfulness of whole words, as opposed to the morphemes in them; (d) length: The number of letters in a word (i.e. word length) or part of a word (e.g. onset length, vowel length, coda length); (e) body-Neighborhood (body-N): The number of words having the same body (vowel + coda letters), based on the analysis of words in a large corpus; (f) bi-gram frequency: The number of words having two adjacent letters, based on the analysis of words in a large corpus; (g) Neighborhood (N): (of a word) The number of words obtained by changing a letter in a position in a word (onset, vowel, or coda), based on the analysis of words in a large corpus; (h) regularity: The condition concerning whether or not a grapheme follows a GPC rule, thus having either the default regular phoneme or another one; (i) feedforward consistency: The consistency of the mapping from letters to sounds (graphemes to phonemes), with focus on the body; and, (j) feedback consistency: The consistency of the mapping from sounds to letters (phonemes to graphemes), with focus on the rime (vowel + coda sounds). All the ten variables above consider the orthographic form of words. The first three variables (word frequency, word familiarity, word semantics) are applicable to the whole-word lexical level, the last six variables (body-N, N, bi-gram frequency, regularity, feedforward consistency, feedback consistency) are applicable to the sublexical level, while the fourth variable (length) can be applicable to the whole-word lexical level (word length) or the sublexical level (e.g. onset length, vowel length, coda length).

Since the variables are numerous and are hard to control in a factorial design in a study, some recent studies (e.g. Balota et al., 2004) have instead used regression analysis to measure the influence of various variables relative to each other. The ten variables defined above are discussed in turn below.

2.3.4.1. Word frequency. As word frequency is estimated by counting word tokens in a large corpus of printed materials, word frequency has been referred to as an “objective frequency” (Balota et al., 2004). Generally, the influence of most other variables is more observable with low-frequency (LF) words rather than high-frequency (HF) words (Balota et al., 2004).

2.3.4.2. Word familiarity. Word familiarity is estimated by asking native speakers to rate their familiarity with words, and as such it has been referred to as "subjective frequency" (Balota et al., 2004). Strong correlation has been obtained between word frequency and word familiarity (Balota et al., 2004). More specifically, Balota, Pilotti, & Cortese (2001) found that most of the variance in word familiarity was accounted for: (a) by word frequency for HF words, and (b) by meaningfulness (i.e. word semantics) for LF words.

2.3.4.3. Word semantics. Balota et al. (2004), describe the interactions of semantic variables with other variables as being "relatively modest" (p. 312). This finding was based on the analysis of words in general. The visual word recognition of two types of words requires the use of word semantics to arrive at the correct pronunciation: (a) exception words, which are irregular (violating a GPC rule) and also have an inconsistent body (e.g. <pint>, as the body <-int> is regular in <hint, mint, print>) (Coltheart & Rastle, 1994); and (b) strange words, which are irregular yet consistent as there are no regular words in the body-N (e.g. <ache, chute>) (Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Strain, Patterson, & Seidenberg, 1995).

As stated above, the three variables above (word frequency, word familiarity, and word semantics) are applicable at the lexical level. Along similar lines, Balota et al. (2004) show that word frequency, word familiarity, and word semantics increase latency in the LDT more than in word naming, because of the greater reliance on lexical processing in the LDT but sublexical processing (of GPC rules) in naming.

2.3.4.4. Length. Word length mainly affects naming latency – not accuracy, and more so with: (a) nonwords than words (length x lexicality interaction), and (b) LF words than HF words (length x word frequency interaction) (Balota et al., 2004). In addition to the lexical whole-word length, the length of sublexical units also influences latency. For instance, onset length greatly influences naming latency (Balota et al., 2004).

2.3.4.5. Body-N, bi-gram frequency, and N. These three variables are based on the analysis of the type frequency of sublexical units. Generally, there is a well-established negative correlation between length and N (shorter words have larger Ns) (Balota et al., 2004; Weekes, 1997). Also, length, N, and body-N are inherently related (Ziegler & Perry, 1998). Balota et al. (2004) found evidence for the influence of N on the naming latency of LF words (word frequency x neighborhood size interaction: LF words with a large N have a shorter naming latency). However, there is evidence that body-N better accounts for naming data than N and bi-gram frequency (Ziegler, Perry, Jacobs, & Braun, 2001).

2.3.4.6. Regularity. Regularity has long been shown to influence naming accuracy and latency in English (Balota et al., 2006). English orthography has been described as being “very irregular” (Treiman et al., 1995, p. 112), as being “a quasiregular system” (Seidenberg & McClelland, 1989, p. 525), and as being “not as irregular as is often implied” (for regularity is sacrificed for fewer letters and a clear morphology in English) (Rayner et al., 2001, p. 34). More specifically, regularity is a categorical distinction (a word is either regular or irregular), and it is defined at the grapheme unit (Balota et al., 2006; Zevin & Seidenberg, 2006).

A grapheme represents only one regular phoneme, possibly in addition to one or more irregular ones (found in irregular words). The correspondence between a grapheme and its regular phoneme is stated in a GPC rule (e.g.

<i>→/ɪ/, as in <hint, mint, print> /ɪ/ but not in <pint> /aɪ/). As stated above, most of the irregularities in English are in the spelling-to-sound (more accurately, grapheme-to-phoneme) correspondences of vowels rather than consonants (Andrews & Scarratt, 1998; Berent & Perfetti, 1995; Treiman et al., 1995; Venezky, 1970; Zevin & Seidenberg, 2006).

Berndt, Reggia, & Mitchum (1987) provide two exhaustive lists of English graphemes (69 vowels, 99 consonants). Similarly, Seidenberg et al. (1994) provide three lists of "orthographic representations" (i.e. graphemes) in English, in which they identify 27 vowels, 33 onset consonants, and 48 coda consonants. Somewhat similarly, Andrews & Scarratt (1998) provide two lists of the GPC rules used in their nonword naming study (16 for vowels, 35 for consonants).

2.3.4.7. Feedforward consistency. The basic idea underlying feedforward consistency is that the sublexical orthographic form of words influences the visual word recognition of words and nonwords having a similar form by means of the analogy that readers make between similarly-spelled words (e.g. the words <wave, have> and the nonword <tave>). The (feedforward) consistency variable was first discovered by Glushko (1979). Glushko (1979) found the analogical account (emphasizing the effect of the lack of consistency) to be distinct from the account based on GPC rules (emphasizing the effect of the lack of regularity). By manipulating the regularity and consistency of the body, Glushko (1979, Experiment 3) studied the naming latency and accuracy of three types of words: (a) regular-consistent (e.g. <haze>; latency: 529 ms; errors: 0.5%), (b) regular-inconsistent (e.g. <wave>; latency: 546 ms; errors: 2.9%), and (c) irregular-inconsistent/exception (e.g. <have>; latency: 550 ms; errors: 8.3%)

[13]. There was thus a gradual increase in latency and errors in the three groups of words. The longer latency and more errors with regular-inconsistent words than regular-consistent ones can be accounted for in terms of consistency but not regularity (Glushko, 1979).

Consistency has since been extensively recognized as a variable influencing visual word recognition. It has been adopted as the basis for the connectionist framework of word reading, a framework first developed by Seidenberg & McClelland (1989) and later improved upon by Plaut et al. (1996), Harm & Seidenberg (2004), and others. Connectionism is a well-supported alternative to the Dual-Route Cascaded (DRC) model of word reading (e.g. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). It is on words with a regular-inconsistent body that the DRC and the connectionist framework differ, for the DRC does not account for their longer latency and lower accuracy while the connectionist framework does (Zevin & Seidenberg, 2006).

Regularity and consistency overlap, for many irregular words are also inconsistent (Zevin & Seidenberg, 2006). Although they had been confounded in the past, regularity and consistency are distinct sublexical variables (Balota et al., 2006; Cortese & Simpson, 2000). Unlike regularity, which is defined in terms of graphemes, consistency is usually defined at the body/rime level, though other orthographic units (e.g. letter) may also be considered (Balota et al., 2006; Zevin & Seidenberg, 2006). Regularity is also a categorical variable, whereas consistency is a continuous variable (e.g. a body can be slightly inconsistent, very inconsistent, and so forth) (Zevin & Seidenberg, 2006).

13 Glushko (1979) recognized a fourth type of words: irregular-consistent (e.g. <laugh, schism>). Owing to the very small number of words having the same body (sometimes only a single word), he considered this type to be inappropriate for the study of the consistency effect.

Jared, McRae, & Seidenberg (1990) put forth a formula for calculating consistency, a formula which has since been widely used (e.g. Balota et al., 2004). In this formula, consistency is calculated by dividing the summed token frequency of the “friends” (words sharing the same body and the same pronunciation, e.g. <flint, glint, hint, mint, print, splint> /ɪ/) by the summed token frequency of all the friends and “enemies” (words sharing the same body but having a different pronunciation, e.g. <pint> /aɪ/). Using a factorial design, Jared (1997) found consistency to yield longer latency and more errors in the naming of not only LF words but also HF words. Similarly, in their regression study, Balota et al. (2004) found that the consistency of the body influences the accuracy in the naming of both LF and HF words.

There is evidence that the effect of the lack of consistency is orthography-based and it results from learning to read a language having an inconsistent (deep/opaque) orthography but not one having a consistent (shallow/transparent) orthography. For example, comparing pre-readers (aged 5) and beginning readers (aged 6) in English (highly inconsistent) and German (highly consistent), Goswami, Ziegler, & Richardson (2005) found that the consistency effect emerged with English beginning readers but not German beginning readers.

2.3.4.8. Feedback consistency. The feedback sound-to-spelling consistency effect was initially obtained using the LDT (Stone, Vanhoy, & Van Orden, 1997; Ziegler, Montant, & Jacobs, 1997a) but not the word naming task (Ziegler et al., 1997a). For example, the feedback-inconsistent rime /-ip/ (found in the bodies <-eap> and <-eep>, e.g. <leap, keep>) may cause longer latency and more errors in the LDT than the feedback-consistent rime /-ʌst/ (found in the body <-ust> only, e.g. <dust, rust>). An analysis of 2,694 monosyllabic English words by Ziegler, Stone, & Jacobs (1997b) shows that feedback inconsistency is more widespread (72.3%) than feedforward inconsistency (30.7%).

In their regression analyses, Balota et al. (2004) found evidence for feedback consistency in word naming but not in the LDT, the exact opposite finding of prior studies (i.e. Stone et al., 1997; Ziegler et al., 1997a). More recently, Ziegler, Petrova, & Ferrand (2008) describe the feedback consistency hypothesis by Stone et al. (1997) as being “one of the most intriguing and counterintuitive hypotheses in the history of visual word recognition” (p. 643). In a number of experiments (using the same items in the LDT with visual and auditory modalities), Ziegler et al. (2008) show that feedback consistency is relevant for auditory – not visual – word recognition, a conclusion which is widely supported in the literature using different tasks in English and French (e.g. Perre & Ziegler, 2008; Ziegler & Ferrand, 1998; Ziegler, Ferrand, & Montant, 2004).

2.3.4.9. Conclusion. While latency in visual word recognition, tested in naming, may be influenced by many of the ten variables discussed above (especially onset length and onset consistency), accuracy (usually of the vowel) in naming is mainly influenced by two sublexical variables: regularity (mostly of the vowel) and feedforward consistency (mainly of the body) (Balota et al., 2004; Cortese & Simpson, 2000; Jared, 2002). Given the focus on accuracy in visual word recognition – tested in naming – in the current study, the variables of regularity and consistency in naming are further elaborated on next.

2.3.5. Effects of the lack of regularity and consistency. Three influential studies using the nonword naming task are reviewed below: Glushko (1979), recognizing orthographic consistency based on non-regular analogy; Andrews & Scarratt (1998), distinguishing the influence of GPC rules from non-regular analogy; and, Seidenberg et al. (1994), showing the gradual nature of non-regular analogy reflecting the number of pronunciations a body has.

Glushko (1979) found consistency to influence the latency and accuracy (i.e. error rates) in the naming of nonwords when intermixed with words (Experiment 1) and nonwords with no words (Experiments 2), as outlined below:

Table 2.6. Latencies and error rates (Glushko, 1979)

	Experiment 1			Experiment 2		
Type of Word / Nonword	Examples	Latency in ms	Error Rate %	Examples	Latency in ms	Error Rate %
Regular Word	dean	589	1.9			
Exception Word	deaf, tomb	618	12.2			
Regular Nonword	hean	617	6.2	bink	609	5.3
Exception Nonword	heaf, tave	646	21.7	bint	631	12.3

In Glushko (1979, Experiment 1), words with an inconsistent body (e.g. <deaf> /dɛf/ vs. <leaf> /lif/) had a longer latency and more errors than words with a consistent-regular body (e.g. <dean> /din/). Of the 12.2% errors in exception words, 10.4% were regularization errors (e.g. <deaf> as */dif/, in line with the GPC rule <ea>→/i/), while most of the remaining 1.8% errors resulted from analogy with exception words (e.g. <tomb> as */tom/ on account of the irregular word <comb> /kom/). Very similar findings were obtained with the nonwords in Experiment 1. That is, nonwords with an inconsistent body (e.g. <heaf, tave>) yielded a longer latency and more errors (i.e. non-regular pronunciations) than those with a consistent body (e.g. <hean>). The vowel in the exception nonwords: (a) 78.3% of the time conformed to the GPC rule (e.g. <heaf> as /hif/,

<tave> as /tev/), (b) 17.6% of the time was influenced by analogy with irregular word(s) (e.g. <heaf, tave> as /hɛf, tæv/, on account of <leaf, have>), and (c) 4.1% of the time was influenced by neither a GPC rule nor an analogy. The same pattern was observed in Experiment 2 where the test items comprised only nonwords, which suggests that mixing words with nonwords (Experiment 1) does not influence nonword naming performance. Importantly, Glushko (1979) shows that the consistency effect is orthographic, is based on the sublexical "analogies" with irregular words having the same body that readers unconsciously make during visual word recognition, analogies which are contrasted with the use of the GPC "rules" the readers may have internalized while learning to read.

Andrews and Scarratt (1998) clarify that there are two types of analogies: regular analogy, and non-regular analogy. That is, words and nonwords with a regular-consistent body (e.g. <dean, hean>) may be named by rule (i.e. <ea>→/i/) or by "regular" analogy with regular words (e.g. <bean, clean, mean>). Andrews and Scarratt (1998) state that Glushko (1979) focused on the latter but made an "implicit argument" (p. 1059) about the former.

Andrews & Scarratt's (1998) aimed to compare the role of two factors influencing nonword naming performance: GPC rules / regular analogy vs. non-regular analogy (no means of distinguishing GPC rules from regular analogy is available). Andrews & Scarratt (1998, Experiment 2 [14]) manipulated the consistency, regularity, and the size of the body-N of monosyllabic nonwords, thus yielding four types of bodies, as outlined below:

14 Two lists were used in Andrews & Scarratt (1998, Experiment 2), one consisting only of nonwords and one having the same nonwords intermixed with words. The results using the two lists were "almost identical" (p. 1070). The findings in Table 2.7 are for the nonword-only list. Similarly, as stated above, Glushko (1979) obtained the same findings when intermixing nonwords with words (Experiment 1) and when using only nonwords (Experiment 2).

Table 2.7. Four types of nonwords (Andrews & Scarratt, 1998)

Type of Body	Ex-ample	Lat-ency	Regular Pronunciation			Non-Regular Pronunciation		Else
			GPC Rule	Example	%	Example	%	%
Consistent-Regular	hing	603	<i>→/ɪ/	/ɪ/ ring	93 ↑	–	0 ↓	7
Inconsistent	pome pook	622	<o_e>→/o/ <oo>→/u/	/o/ home /u/ spook	88 ↑	/ʌ/ come /ʊ/ book	9 ↓	3
NRA-Unique	bealm	685	<ea>→/i/	–	41 ↑	/ɛ/ realm	40 ↓	19
NRA-Many	dalt	646	<a>→/æ/	–	19 ↑	/ɔ/ salt	66 ↓	15

Nonwords with a consistent-regular body (e.g. <hing> /hɪŋ/) had the highest percentage of the regular pronunciation, which may have resulted from vowel GPC rules (i.e. <i>→/ɪ/) or from "regular" analogy (e.g. with <ring, sing>). Nonwords with an inconsistent body mainly had the regular pronunciation, even when the body-N had: (a) HF irregular word(s) (e.g. <pome> as /pom/, in spite of <come, some> /ʌ/), or (b) many irregular words (e.g. <pook> as /puk/, despite <book, brook, cook, crook, hook, look, shook, took> /ʊ/ but not <spook> /u/). The two non-regular analogy (NRA) groups are: (a) NRA-Unique, with a single irregular word in the body-N (e.g. <bealm> as /bɛlm/, based on <realm> /ɛ/); and (b) NRA-Many, with many irregular words in the body-N (e.g. <dalt> as /dɔlt/, in line with <halt, salt, Walt> /ɔ/).

Concerning the empty cells for example English words in the table above, a consistent-regular body is by definition not found in any irregular word (i.e. non-regular analogy is not possible). Conversely, an NRA body is by definition found only in irregular words. Given that the pronunciation of an NRA nonword may be arrived at by either a GPC rule or by non-regular analogy, this characteristic renders the NRA group the only means for distinguishing between the role of GPC rules and the role of non-regular analogy.

All the differences in latency were significant except for that between the first and second groups. The two NRA groups yielded longer latency than the two remaining ones, and latency was shorter with NRA-Many than NRA-Unique. Regarding accuracy, the researchers' findings may be summarized as follows: (a) There was little individual variation between participants on the chosen pronunciations (e.g. for about two thirds of the test items, there was agreement between at least 90% of the participants); (b) The influence of GPC rules was always present, yet it was counter-balanced by the influence of non-regular analogy – as indicated by the arrows going in different directions in the table above; and, (c) Within the two consistent-irregular NRA groups, the non-regular pronunciation was obtained more with the NRA-Many group than the NRA-Unique group regardless of the summed token frequency of the words in the body-N in both cases.

The findings of Andrews & Scarratt's (1998) study illustrate the effect of the lack of regularity. That is, comparing the use of the regular vowel in the consistent-regular group and the two consistent-irregular NRA groups (all three being consistent), the two NRA groups yielded less accuracy and longer latency, hence an effect of the lack of regularity.

On the other hand, the effect of the lack of consistency may be shown in Seidenberg et al.'s (1994) nonword naming study, in which there was a large agreement between participants on the accuracy and latency of pronunciations reflective of the number of pronunciations a body has, as shown below:

Table 2.8. Influence of consistency (Seidenberg et al., 1994)

Number of Nonwords	First Pronunciation		Second Pronunciation		Third Pronunciation	
	Accuracy	Latency	Accuracy	Latency	Accuracy	Latency
206	97.1	656 (3.6)				
269	83.4	692 (4.1)	12.1	700 (8.6)		
100	60.7	744 (8.1)	23.4	753 (10.7)	10.4	787 (18.7)

Nonwords having a consistent body mainly had one pronunciation with the highest accuracy (97.1%), shortest latency (656 ms), and smallest standard deviation (SD) (3.6) (SDs are in parentheses). As the number of pronunciations increased, there was a gradual decrease in the accuracy of the first pronunciation (83.4% with two pronunciations, 60.7% with three pronunciations) and a gradual increase in the latency and SD of the first pronunciation (692 ms and 4.1 with two pronunciations, 744 ms and 8.1 with three pronunciations). That is, the degree of consistency influences the naming performance.

2.3.6. Summary. Visual word recognition is a lower-level psycholinguistic matching process in silent reading, from visual letter strings (input) to orthographic, phonological and semantic representations in the mental lexicon (output). The skill in this process increases with exposure to and experience with printed words. The same is true for spelling knowledge, as the same mental lexicon is used in visual word recognition (decoding) and in spelling out words (encoding) (section 2.3.1). There is phonological activation during this process, as supported by behavioral data in which there is no phonological output (e.g. LDT, semantic categorization, semantic priming) and eye-movement data (i.e. parafoveal preview) (section 2.3.2). Different skills underlie phonological and orthographic processing in this process (section 2.3.3).

Generally, of the numerous variables influencing visual word recognition, ten are well studied, and they may be categorized at the lexical versus sublexical level (section 2.3.4). At the lexical level, they include: word frequency, word familiarity, word semantics, and length (of the word). At the sublexical level, they include: length (of the onset, vowel, coda, etc.), body-N, bi-gram frequency, N, regularity, feedforward consistency, and feedback consistency. While latency is mainly influenced by onset variables (onset length and consistency), accuracy is mainly influenced by two variables: regularity and (feedforward) consistency.

The influence of the lack of regularity and the lack of consistency is expounded on in three studies using the nonword naming task (section 2.3.5): (a) Glushko (1979), proposing the effect of consistency as distinct from that of regularity; (b) Andrews & Scarratt (1998), showing that the influence of GPC rules is counter-balanced by non-regular analogy; and, (c) Seidenberg et al. (1994), showing the gradual effect of the degree of consistency. Certain combinations of consonant and vowel graphemes seem to have a high consistency and/or a large body-N despite their irregularity, thus suggesting the influence consonants have on vowels, as elaborated on in the following section.

2.4. Processing Consonants and Vowels in English

A number of studies have looked into the relation between consonants and vowels and/or the influence of this relation on processing in visual word recognition. Four major areas may be distinguished: (a) the earlier processing of consonants than vowels, (b) the analysis of English words, (c) sensitivity to the consonantal context of vowels, and (d) the role of rules.

2.4.1. Earlier processing of consonants than vowels. There is evidence that consonants are processed slightly earlier than vowels during visual word recognition in English, which is ascribed to the low feedforward spelling-to-sound consistency of English vowels. This evidence has been obtained in two types of studies: (a) letter detection with backward priming in English (Berent & Perfetti, 1995), though a replication found no temporal difference in Italian wherein vowels have a high spelling-to-sound consistency (Colombo, Cubelli, Zorzi, & Caporali, 1996); and (b) eye movements with either delaying a consonant and/or a vowel letter (Lee, Rayner, & Pollatsek, 2001) or priming a consonant and/or a vowel letter (Lee, Rayner, & Pollatsek, 2002). Lee et al. (2001) attribute the earlier processing of vowels than consonants to vowels having less spelling-to-sound consistency than consonants in English – an explanation that had been acknowledged and considered by Berent & Perfetti (1995). Furthermore, Lee et al. (2002) argue that the cause is not the low consistency of the “actual vowel sounds encountered” per se but rather “the generally greater inconsistency of vowels in English” (p. 769).

2.4.2. Analysis of English words. There is evidence that certain consonants influence certain neighboring vowel sounds in English, as found in the analysis of English words, discussed below in the work by Venezky (1970), Treiman et al. (1995), and Kessler & Treiman (2001). Venezky (1970) details the regularities in spelling patterns in English along with their exceptions, with more focus on the latter. In terms of the spelling-to-sound correspondences at the vowel-letter level, Venezky (1970) describes English orthography as showing “no regularity” (p. 101) (e.g. the letter <o> represents 17 vowel sounds, <a> ten, and <e> nine). However, when the morphemic structure and the “consonant environment of words” (p. 101) are taken into account, regularity in pattern emerges, exceptions notwithstanding.

More specifically, Venezky (1970) recognizes three main types of “consonant influences” on vowels: an onset <w/u> /w/, a coda <l> /l/, and a coda <r> /ɹ/. First, an onset <w/u> /w/ results in the letter <a> being pronounced /ɑ/ instead of /æ/ (e.g. <want, squad>), provided that the coda is not a velar consonant (e.g. <wax, wag, Wang, quack> /æ/) or an /ɹ/ (e.g. <war, quart> /ɔ/). Second, a coda <l> /l/ results in: (a) the letter <a> usually being pronounced /ɔ/ instead of /æ/ (e.g. <call, bald, talk> but not <shall> /æ/), and (b) the letter <o> almost always being pronounced /o/ instead of /ɑ/ (e.g. <roll, jolt, told, folk> but not <doll> /ɑ/). And, third, a coda <r> /ɹ/ exerts an extensive influence that may be summarized as follows: (a) the letter string <-ar-> is pronounced /ɑɹ/ instead of /æɹ/ (e.g. <car>), (b) the lax/short vowels /ɪ, ɛ, ʌ/ become syllabic <r> /ɚ/ (e.g. <sir/Byrd, her, fur>), and (c) the tense/long vowels /i, e, u, o/ respectively become the lax/short vowels /ɪ, ɛ, ʊ, ɔ/ (e.g. <fear, hair, tour, more>).

Venezky (1970) also recognizes “miscellaneous consonant influences.” These are summarized below under the following two groups: (a) a group with no exceptions having the following bodies (with examples in parentheses): <-ign> (<sign> /aɪ/), <-igh> (<high> /aɪ/), <-ight> (<right> /aɪ/), <-eigh> (<weigh> /e/), <-aught> (<caught> /ɔ/), and <-ought> (<bought> /ɔ/); and, (b) a group with exceptions: <-ind> (<find, kind, mind> /aɪ/ vs. <wind> /ɪ/), <-ild> (<child, mild, wild> /aɪ/ vs. <gild> /ɪ/), <-eight> (<height, sleight> /aɪ/ vs. <eight> /e/), and <-ough> (<rough> /ʌ/, <dough> /o/, <through> /u/, vs. <bough> /aʊ/).

Treiman and colleagues demonstrate that the consistency of the body (vowel + coda letters) is higher than the consistency of the vowel, the former unit being larger than the latter. Treiman et al. (1995, Part 1) measured the spelling-to-sound consistency of 1,329 monosyllabic, monomorphemic English CVC words (with one onset consonant, one vowel, and one coda consonant) in the following five orthographic units: onset, vowel, coda, onset+vowel unit (head), and vowel+coda unit (body). Based on type and token frequency, the consistency of consonants (onset = .94 type / .96 token; coda = .92 type / .91 token) was – as predicted – higher than the consistency of vowels (.62 type / .51 token [15]). More importantly, the consistency of bodies (.80 type / .77 token) was higher than the consistency of vowels (.62 type / .51 token), while the consistency of heads (.55 type / .52 token) was comparable to the consistency of vowels (.62 type / .51 token). In other words, the correspondence within the body-rime unit is more consistent than the correspondence within the vowel grapheme-phoneme unit. Treiman et al. (1995, Part 1) conclude that the vowel sound is more predictable when the coda is taken into account.

Kessler & Treiman (2001) replicated this finding in their analysis of 3,117 monosyllabic, monomorphemic English words [16]. The researchers limited their calculation of consistency to a type-based frequency rather than a token-based frequency [17]. The researchers compared two types of feedforward consistencies: (a) the consistency of a vowel grapheme regardless of the other consonant or consonant cluster (termed "unconditional consistency"), and (b) the consistency of the same vowel grapheme when the onset or coda is occupied by a certain consonant or consonant cluster (termed "conditional consistency"). As expected,

15 The lower consistency of vowels using token frequency than type frequency reflects the fact that many irregular words in English have a very high token frequency.

16 The 3,117 words comprise the 1,329 CVC words from the 1995 study, in addition to words with onset and/or coda positions that are either empty or are occupied with a consonant cluster.

17 The use of type frequency is justified on the grounds that it is in line with "the logic of the English orthographic system" (p. 605) wherein each word type should ideally have a unique, invariable spelling. For example, they state that the letter <f> always has the pronunciation /f/ except in the HF word <of> /v/. Owing to the high frequency of <of>, a token-frequency approach to consistency will render the consistency of the <f>-/f/ correspondence weaker while that of <f>-/v/ stronger, hence a violation of the logic of the English writing system.

the unconditional consistency of vowels (.717) was lower than that of the onsets (.976) and codas (.982). More importantly, the low unconditional consistency of .717 of vowels: (a) significantly improved to the conditional consistency of .920 (a 13.6% improvement) when the coda was taken into account; but, (b) insignificantly improved to the conditional consistency of .807 (a 0.1% improvement) when the onset was taken into account. Kessler & Treiman (2001) conclude that the vowel sound is conditioned by the coda consonant(s) – not the other way around. Kessler & Treiman (2001) provide a list of English feedforward spelling-to-sound correspondences [18]. For example, the letter <a> is /æ/ by default (e.g. <cat>), and it is /ɑ/ word-finally (e.g. <spa>), /e/ before <-nge> (e.g. <change>), and /ɔ/ before <-ld> (e.g. <bald>).

Treiman and colleagues attribute most of the irregularities in English to spelling conventions and to sound changes whereby the pronunciation of words changed but the spelling did not. Two spelling conventions and five sound changes are recognized. The two spelling conventions are: (1) the disallowance of <wu> (e.g. <word, work> instead of the incorrectly spelled <wurd, wurk>, all of which having a syllabic <r> /ɚ/), and (2) the disallowance of <oul, oun> (e.g. <howl, down> instead of the incorrectly spelled <houl, doun>, all of which having the diphthong /aʊ/) (Treiman, Kessler, & Bick, 2002). The five sound changes are: (1) using word-final <e> as a marker of vowel length (e.g. <cave, wave>, but not <have>); (2) <i> /ɪ/ becoming /aɪ/ before /ld, nd/ (e.g. <wild, mind>, but not <wind> /ɪ/); (3) <ea> /i/ becoming /ɛ/ before /d/ (e.g. <dead, head>, but not <bead>); (4) long vowels in AE becoming short before /ɹ/ (e.g. <rare> /eɹ/→/ɛɹ/,

18 In addition to the list of feedforward, spelling-to-sound correspondences (relevant to decoding: reading words), the researchers also provide a list of the feedback, sound-to-spelling correspondences (relevant to encoding: spelling out words).

<hoarse> /oɹ/→/ɔɹ/); and (5) <a> /æ/ taking on lip-rounding after an onset /w/ resulting in: (5a) <a> becoming rounded /ɒ/ and subsequently unrounded /ɑ/ (e.g. <watch>), provided that the coda is not a velar stop (e.g. <wax, wag, Wang, quack> /æ/), or (5b) <a> becoming /ɔ/ before an /ɹ/ (e.g. <war>) (Kessler & Treiman, 2001; Treiman et al., 2002).

2.4.3. Sensitivity to the consonantal context of vowels. AE native speakers have sensitivity to the correspondences between consonants and vowels in English words. Treiman and colleagues used three types of studies to test this sensitivity: (a) a regression study of word naming data (Treiman et al., 1995, Part 2), (b) a word naming study (Treiman et al., 1995, Part 3), and (c) two nonword naming studies, with adults (Treiman, Kessler, & Bick, 2003) and children (Treiman, Kessler, Zevin, Bick, & Davis, 2006).

Based on their regression analysis of two word naming mega-studies (their own collected data of 1,327 monosyllabic English CVC words, and Seidenberg & Waters's (1989) data of 2,897 monosyllabic English words), Treiman et al. (1995, Part 2) report the following robust finding obtained in both mega-studies and in all the regression analyses therein: Words with an inconsistent body yielded longer latency and larger error rates than those with a consistent body.

In a word naming experiment, Treiman et al. (1995, Part 3) found the following: (a) Words with a body having a low consistency (e.g. <-ood>, regular /od/ in <food, mood>, irregular /ʊd/ in <good, stood> and /ʌd/ in <blood, flood>) yielded higher error rates than words with a body having a high consistency (e.g. <-um>, always regular /ʌm/ as in <gum, hum>), yet (b) Words with a body having a low consistency did not yield longer latency.

Treiman et al. (2003) used the nonword naming task to study eight cases of heads and bodies having a high consistency (based on Kessler & Treiman, 2001) despite the irregularity of the vowel in them, the first two in which the onset influences the vowel (“onset-to-vowel association”), and the last six in which the coda does (“coda-to-vowel association”). The larger number of the latter cases is attributed to their being more common in English. In those eight cases, experimental items (having the vowel plus the onset or coda of interest) are compared with control items (having the same vowel with a different onset or coda). The data was collected from 24 adult AE native speakers. The eight cases and the findings (proportion of the critical vowel) are outlined below:

Table 2.9. Eight cases of consonantal context (Treiman et al., 2003)

Case	Critical Vowel and Example	Regular Vowel and Example	Con-sis-tency	Example Nonwords		Proportion of Critical Vowel	
				Experi-mental	Con-trol	Experi-mental	Con-trol
1. /w/-<a>	/ɑ/ swamp, squad	/æ/ camp	.84	twamp	glamp	.64	.06
2. /w/-<a>-/ɹ/	/ɔ/ war, quart	/ɑ/ car	1	wark	vark	.17	.01
3. <-ange>	/e/ change	/æ/ chance	1	blange	blance	.59	.05
4. <-ald / -alt>	/ɔ/ bald, salt	/æ/ band, rant	1	nald	tand	.94	.08
5. <-ead>	/ɛ/ head	/i/ beam	.69	clead	cleam	.13	.01
6. <-ind / -ild>	/aɪ/ mind, mild	/ɪ/ mint, tilt	.89	crind	crint	.35	.02
7. <-old / -olt>	/o/ gold, bolt	/ɑ/ pond, font	1	brold	brond	.88	.05
8. <-ook>	/ʊ/ book	/u/ moon	.94	blook	bloon	.70	.00

For example, in Case 1 (/w/-<a>), the letter <a> is pronounced /ɑ/ following /w/ as in <swamp, squad>, yet <a> is regularly pronounced /æ/ as in

<camp>. The consistency of the <wa>–/wɑ/ correspondence in English is 84%. The proportion of the critical vowel /ɑ/ was 64% with the experimental items (e.g. <twamp>) but 6% with the control items (e.g. <glamp>). As shown in the last two columns, the proportion of the critical (irregular) vowel pronunciation was across the board higher with the experimental items than the control items. Moreover, the proportion of the critical vowel varied wildly between cases (ranging from a high of 94% in Case 4 to a low of 13% in Case 5), and the researchers acknowledge not being able to account for this large variation. Treiman et al. (2003) conclude that AE native speakers have "sensitivity" to the "consonantal context" of vowels, as evidenced in their pronunciation of vowels in nonword naming.

Treiman et al. (2006) replicated the (2003) study with children learning to read in grades 1, 3, 5, 8, as well as teenagers in high school. Small differences between the means of the critical vowel in the experimental vs. control items were obtained from as early as grade 1, and these differences progressively widened in grades 3 and 5. After grade 5, however, the differences did not change in a reliable fashion, yet they continued to approximate those obtained from adult college students in Treiman et al. (2003). Treiman et al. (2006) state that the influence of the consonantal context was observable from the very beginning stages of learning to read despite teaching methods such as phonics aiming at teaching the typical pronunciation of graphemes. Such teaching methods, it is argued, may have reduced the differences between the means of the critical versus typical vowel in grade 1.

Treiman et al. (2003) state that the vowel in many irregular words is predictable from the influence of the onset (e.g. <wand>, Case 1), coda (e.g.

<dread, bind, brook>, Cases 5, 6, and 8, respectively), or both (e.g. <warn>, Case 2). At least these words are not as irregular as the word <plaid>, which is “truly irregular” (p. 72) as there is no explanation for its irregular pronunciation (i.e. the vowel /æ/ is not predictable from the onset or the coda). Moreover, Treiman et al. (2003) carried out their own analysis of the experimental items used in 17 word naming studies (published between 1991 and 2001), and they found that nine of these 17 studies contained items regarded as irregular but which are regular when context is considered. That is, few studies mixed phonologically predictable exceptional words (e.g. <wand>) with less predictable ones (e.g. <plaid>).

2.4.4. Role of rules. Explicating the role of rules is relevant for understanding the processing of consonants and vowels in English, as some rules may reflect the consonantal context of vowels. That is, rules may apply to different unit sizes, namely: non-contextual (i.e. a GPC rule applies to one grapheme and one phoneme), and contextual (i.e. phonological rules apply to two or more phonemes). The question of the role of rules in visual word recognition is controversial, as discussed below.

Proponents of the connectionist framework do not favor the use of GPC rules. In word naming, Glushko (1979, Experiment 3, section 2.3.4.7) shows that the effect of consistency can be explained by analogy but not by rules. That is, rules do not explain the longer latency and more errors with regular-inconsistent words (e.g. <wave>), but non-regular analogy does (i.e. <wave> on account of <have>). Similarly, in nonword naming, Glushko (1979, Experiment 1, section 2.3.5) argues that nonwords “are not pronounced solely through the operation of abstract spelling-to-sound rules” (p. 680), as about 18% of the irregular pronunciations obtained resulted from non-regular analogy (e.g. <tave> as /tæv/, on account of <have>).

Using stronger terms, following their extensive criticism of the treatment of rules in the DRC model, Seidenberg et al. (1994) advocate the “alternative” to “abandon the commitment to the rule formalism entirely in favor of” the analogical account in connectionism (p. 1188). The empirical support for this argument is based on their analysis of nonwords having an inconsistent body, as there was a gradual change in accuracy and latency reflecting the number of pronunciations a body has (Table 2.8 above). According to the researchers, this gradual change can be explained in terms of the role of non-regular analogy – not in terms of the role of GPC rules. The same claim is also made by Zevin & Seidenberg (2006).

Analogies alone, however, may not suffice to explain the naming performance. More specifically, Venezky & Massaro (1987) state that analogies alone can not account for: (a) nonwords such as <tebe, fibe, lufe, soge>, the bodies in which are not found in any English word; (b) the pronunciation of word-initial clusters in words; or, (c) the pronunciation of polysyllabic words. Moreover, Andrews & Scarratt (1998, section 2.3.5) state that some of their findings are not in line with the connectionist account of word reading, which are: (a) the dominant role of GPC rules, (b) the role of type frequency with consistent-irregular NRA nonwords (more accuracy with NRA-Many than NRA-Unique), and (c) the little effect of token frequency with nonwords having an inconsistent body. Not only are these findings incompatible with the connectionist framework (emphasizing analogy and token frequency), but they are also in line with the DRC model (emphasizing rules and type frequency). The GPC rules in Andrews & Scarratt (1998), however, are described by Zevin & Seidenberg (2006) (working within the connectionist framework) as being “minimalist” (as opposed to the elaborate ones in the DRC model).

In addition to GPC rules, Andrews & Scarratt (1998) state that there are some phonological rules operating at the contextual level with units larger than the grapheme, e.g. the letter string <-ar-> (as in <car>) is pronounced /ɑɹ/ instead of /æɹ/. Similarly, Treiman & Kessler (2007) recognize the following phonological rule: Vowels are tense (and slightly longer) in open syllables (e.g. <e> as /i/ in <be>, violating the GPC rule <e>→/ɛ/), but not so in closed ones (e.g. <bed>, complying with the GPC rule <e>→/ɛ/). Thus, two types of rules are recognized by Andrews & Scarratt (1998): GPC rules (at the grapheme-phoneme level), and phonological rules (contextual, operating between two or more phonemes or taking into account a syllable structure).

The influence of orthographic non-regular analogy is arguably contextual, based on the body. Converging evidence for the claim that English readers need to use units larger than the grapheme (such as the head and/or the body) during visual word recognition include the work by Treiman and colleagues (sections 2.4.2 and 2.4.3), Glushko (1979) (sections 2.3.4.7 and 2.3.5), and Andrews & Scarratt (1998) (section 2.3.5). It is unclear, however, whether these larger units are accounted for by phonological rules or by orthographic non-regular analogy, as both of these factors operate at the contextual level.

2.4.5. Summary. Four areas of the study of the processing of consonants and vowels in English have been discussed. First (section 2.4.1), data from letter detection and eye movements show that consonant letters are processed earlier than vowel letters in English, a finding which has been attributed to the low consistency of vowels in general relative to consonants.

Second (section 2.4.2), Venezky (1970) recognizes three main types of "consonant influences" on vowels (i.e. onset <w, u> /w/, coda <l> /l/, coda <r> /ɹ/), and a few cases of "miscellaneous consonant influences." Similarly, in their analysis of English words, Treiman and colleagues detail the spelling-to-sound correspondences between consonants and vowels, and they show that the body is more consistent than the vowel alone. Spelling conventions and sound changes account for most of the irregularity of vowel letters in English words.

Third (section 2.4.3), Treiman and colleagues elaborate on the influence of the consonantal context of vowels on processing. In word naming, lack of consistency influences accuracy but not latency. AE native speakers' sensitivity to the consonantal context of vowels was reflected more clearly in nonword naming (Treiman et al., 2003; 2006) than in word naming (Treiman et al., 1995).

And, fourth (section 2.4.4), two types of rules are distinguished: GPC rules at the grapheme-phoneme level, and phonological rules at the contextual level between phonemes. Like phonological rules, orthographic non-regular analogy also operates at the contextual level, between graphemes.

2.5. Summary of Chapter 2

The study of L2 visual word recognition falls within the cognitive theory of L2 acquisition within the field of SLA. The problem area that is reviewed is Arab ESL learners' relatively poor visual word recognition skills in ESL, compared to non-Arab ESL learners (section 2.1). These poor skills have been attributed to: (a) negative L1 transfer of the strategy of focusing on consonant letters, and (b) poor L2 spelling knowledge. In terms of transfer influencing Arab ESL visual word recognition, Arab ESL learners do not have the positive transfer resulting in greater focus on orthographic processing, do not have familiarity with the Roman alphabet, and it may be the case that they are little influenced by the depth of English. There is a comparison between the vowel phonemes in AE and in Gulf Arabic, as well as a review of Arab ESL learners' lack of accuracy in producing AE vowel phonemes (section 2.2).

An overview of the study of visual word recognition by AE native speakers (section 2.3) looks into five areas: (a) the positive relation between efficiency in visual word recognition and the amount of exposure to and experience with printed materials; (b) the automatic activation of phonology during visual word recognition; (c) the skills underlying phonological vs. orthographic processing; (d) ten variables influencing visual word recognition, two of which influence accuracy in the naming task: regularity (mostly of vowels) and consistency (mainly of the body); and (e) the effects of the lack of regularity and consistency.

Moreover, certain consonants influence certain adjacent vowels in English (section 2.4). Consonants letters are processed slightly earlier than vowel letters in English. Venezky (1970) focused on the systematic regularity of irregular words in spelling, and he recognized cases of consonantal influence on vowels. Treiman and colleagues statistically quantified the relation between consonants and vowels in their study of corpora of English words, and they also studied AE native speakers' sensitivity to the consonantal context of vowels. The treatment of rules in the literature suggests that there are two types of rules: GPC rules (non-contextual, between a grapheme and a phoneme), and phonological rules (contextual, between phonemes). Orthographic non-regular analogy similarly operates at the contextual level, between graphemes based on the body. The distinction between these three factors (GPC rules, phonological rules, and orthographic non-regular analogy) is elaborated on in the following chapter.

Chapter 3: AE Native Speakers' Vowel Accuracy

As discussed above (section 2.3.5), accuracy in visual word recognition – tested in naming – has been studied in terms of two main variables: regularity (mainly of vowels) and consistency (mostly of the body). The consonantal context of vowels also influences accuracy in naming (section 2.4), yet it is unclear whether this context is phonological or orthographic. The goal in this chapter is to determine the phonological and orthographic properties of English influencing AE native speakers' vowel accuracy in visual word recognition. A distinction is made between phonological properties (between phonemes) and orthographic properties (between graphemes), the influence of both of which run counter to the influence of GPC rules (between a grapheme and a phoneme). This chapter comprises the following: research question and hypothesis, method (experimental design, materials, data collection and analysis), and results and discussion.

3.1. Research Question and Hypothesis

The research question is as follows: Is vowel accuracy in visual word recognition by AE native speakers influenced by phonological and/or orthographic factors of English? The following is hypothesized: In addition to the influence of GPC rules, vowel accuracy in visual word recognition by AE native speakers is influenced by two distinct sources: (a) phonological properties of English (i.e. “phonological constraints”), and (b) orthographic properties of English (e.g. consistency and regularity).

In line with Kessler & Treiman's (2001) recognition that consonants “condition” adjacent vowels in English (section 2.4.2), a distinction is made between the default “regular” vowel (according to GPC rules), and the “conditioned” vowel (conditioned by the consonantal context). Importantly, this contextual conditioning arises from: (a) neighboring consonant phoneme(s) with phonological properties, explicitly stated in phonological constraints; or, (b) neighboring consonant grapheme(s) with orthographic properties, specifically the effects of the lack of regularity and/or consistency. The context may thus be phonological or orthographic. Conceptually, these two sources are distinct as they operate on different planes: phonemes and graphemes (or more simply: sounds and letters), respectively.

Regarding phonological properties, five phonological constraints may be recognized, the first two of which are considered to be strong, while the last three are considered to be weak (justification in the next paragraph). The two strong phonological constraints are: (1) *V_lax# (no lax vowel syllable-finally) [19] (e.g. while <i, e, u, a> yield the lax vowels /ɪ, ɛ, ʌ, æ/ in a closed syllable as in <sit, let, but, hat>, in an open syllable they represent the tense vowels /i, i, u, ɑ/ as in <ski, be, flu, pa> while <i> also represents the diphthong /aɪ/ as in <hi>) (Giegerich, 1992; Hammond, 1997); and, (2) the phonological universal *æɹ (no /æ/ followed by /ɹ/) (e.g. <star> as /stɑɹ/ instead of */stæɹ/) (Kager, 1999; Venezky, 1970). The three weak phonological constraints are: (3) *V_lax+ɹ (no lax vowel followed by /ɹ/), thus yielding syllabic <r> /ɚ/ not /ɪɹ, ɛɹ, ʌɹ/ (e.g. <sir/Byrd, her, fur>) (Veatch, 1991; Venezky, 1970); (4) *wæ+non_velar (no /æ/ between an onset /w/ and a

19 As only tense vowels occur syllable-finally, this distinction is considered to be a test of tenseness (Giegerich, 1992; Hammond, 1997). Giegerich (1992) thus recognizes the following tense vowels /i, e, u, o, ɔ, ɑ/, and the following lax ones /ɪ, ɛ, æ, ʌ, ʊ/.

non-velar coda), in which case /ɑ/ is used (e.g. <swamp, squad>), provided that the coda is neither a velar consonant (e.g. <wax, wag, Wang, quack> /æ/) nor an /ɹ/ (next constraint) (Kessler & Treiman, 2001; Venezky, 1970); and, (5) *wɑɹ (no /ɑ/ between an onset /w/ and a coda /ɹ/), thus resulting in /ɔ/ (e.g. <war, quart>) (Kessler & Treiman, 2001).

The three weak phonological constraints motivated sound changes: the syllabification of /ɹ/ after a lax/short vowel started in the beginning of the 17th century for the goal of achieving full rhoticity (Veatch, 1991), and the onset /w/ resulted in <a> first taking on lip-rounding as rounded /ɒ/ then as unrounded /ɑ/ (if the coda is not a velar consonant or /ɹ/) or as rounded /ɔ/ (if the coda is /ɹ/) (Kessler & Treiman, 2001). In the history of English, these three phonological constraints came to be violated and led to sound changes. For the purpose of the current study, they are hypothesized to be weak.

These five phonological constraints result in a violation of vowel GPC rules, a violation that is explicable in terms of an empty coda (*V_lax#), a coda /ɹ/ (*æɹ; *V_lax+ɹ), an onset /w/ (*wæ+non_velar), or an onset /w/ plus a coda /ɹ/ (*wɑɹ). The vowels used in place of the default regular ones are here conditioned by the neighboring consonant phonemes. None of the five phonological constraints is violated *phonologically*. That is, there is no English word with: (1) a lax vowel syllable-finally (violating *V_lax#), (2) with /æɹ/ (violating *æɹ), (3) with a lax vowel followed by /ɹ/ (violating *V_lax+ɹ), (4) with /wæ/ followed by a non-velar consonant (violating *wæ+non_velar, the only exception being the word <swam> which has a morphological past-form inflection), or (5) with /wɑɹ/ (violating *wɑɹ). The five phonological constraints represent “phonological properties”.

On the other hand, the lack of consistency is considered to reflect "orthographic properties" insofar as orthography has an imperfect correspondence with phonology. Since its inception as a construct, consistency has been described as an orthographic factor (Glushko, 1979, section 2.3.5). Additionally, the degree of consistency differs between languages and the effect of the lack of consistency emerges when children learn to read an inconsistent language rather than a consistent one (Goswami et al., 2005, section 2.3.4.7).

Consistency is calculated using Jared et al.'s (1990) formula (see section 2.3.4.7 for explanation and details). Somewhat similarly, the H statistic was proposed by Fitts & Posner (1967) as a measurement for estimating the probability of a response in a behavioral experiment. The H statistic is calculated using the formula: $\Sigma\ p_i \log_2 (p_i / 1)$, where p_i stands for the probability of an event. In the naming task, p_i is the consistency of a single pronunciation of a body. As elaborated on with examples below (Table 3.5), an inconsistent body has two or more pronunciations each of which having its own consistency value, but it has only one H value (taking into account the relation between the different pronunciations). The H statistic was used in Andrews & Scarratt's (1998) analysis of nonword naming data (section 2.3.5), and in Treiman et al.'s (1995) analysis of the relation between consonants and vowels in monosyllabic CVC English words (section 2.4.2). Treiman et al. (1995) state that H is 0 for words with a consistent body, and H increases when the number of alternative pronunciations of a body increases and when the summed token frequencies of the different pronunciations of a body are similar, as both of these cases increase a participant's uncertainty of their response during a trial in an experiment.

3.2. Method

3.2.1. Experimental design. The experiment has a 2x2 design: type of property (phonological vs. orthographic) x consistency (inconsistent vs. consistent-irregular). There are thus four conditions, as outlined below:

Table 3.1. 2x2 experimental design and four conditions

	Phonological Properties	Orthographic Properties
Inconsistent	phonological properties / inconsistent	orthographic properties / inconsistent
Consistent-Irregular	phonological properties / consistent-irregular	orthographic properties / consistent-irregular

To obtain an effect of consistency, there is a comparison between inconsistent and consistent-irregular letter strings and bodies. This effect of consistency is predicted to be obtained with orthographic but not phonological properties. As stated above, “body” refers to vowel + coda letters. The term “letter string” is used with phonological properties to refer to a combination of vowel and consonant letters at the onset and/or coda. The term “body” may be loosely used to refer to “letter string”, so as to avoid the repetition of the latter term.

3.2.2. Materials. A corpus of 2,641 monosyllabic words with a frequency of 1 or more per million was created from the word frequency norms by Zeno, Ivenz, Millard, & Duvvuri (1995) [20]. This corpus was used to determine the letter strings and bodies falling under the four conditions in Table 3.1. The collected words had the following two properties: (a) all are monosyllabic, and none has a syllabic coda (e.g. <cattle, written>), and (b) all are monomorphemic

20 The Zeno et al. (1995) word frequency norms are based on the analysis of 17,274,580 word tokens, and they contain 154,941 word types. These norms were found to be the best predictor of behavioral data, based on the comparison of five norms (Balota et al., 2004) and three norms (Zevin & Seidenberg, 2002).

(e.g. those having the suffixes <-ed, -s> as in <walked, cats> were removed, yet inflected words such as <ran, seen> were included). The phonological forms of the collected words were added from Webster's New World dictionary & thesaurus (2006) (henceforth Webster's) (CD Edition). The 2,641 words have 2,719 phonological forms, an increase which is attributable to heterophonic homographs [21] and free variation [22]. The table below contains 13 AE vowel phonemes [23] and the 34 vowel graphemes that yield them by default [24]. (The # symbol represents a word boundary).

Table 3.2. Vowel phonemes and default regular vowel graphemes

Type	Phonemes	Graphemes	Examples
Front Vowels	/i/	ea, ee, ie, e_e	each, see, field, these
	/ɪ/	i, y	in, gym
	/e/	ai, ei, ay#, ey#, a_e	main, eight, may, they, made
	/ɛ/	e	when
	/æ/	a	and
Back Vowels	/u/	oo, eu, ew, ue, ui, u_e	too, Zeus, new, true, fruit, use
	/o/	oa, oe#, o_e	boat, Joe, those
	/ɔ/	au, aw	Paul, saw
	/ɑ/	o	not
	/ʌ/	u	but
Diph-thongs	/aɪ/	ie#, ye#, i_e, y_e	die, dye, time, type
	/aʊ/	ou, ow	out, how
	/ɔɪ/	oi, oy	point, boy

21 For heterophonic homographs, the frequency in the Zeno et al. (1995) word frequency norms was divided proportionately between the two (or more) pronunciations. For example, the 114 per million token frequency for <lead> is divided into 95 for /lɛd/ and 19 for /lid/, based on the percentage of the raw token frequency of these two words in the word naming study by Kessler, Treiman, & Mullennix (2003) (i.e. /lɛd/ 92,660 or 83%, and /lid/ 19,329 or 17%).

22 The first pronunciation in Webster's was considered, while remaining one(s) were disregarded.

23 Excluded are the schwa /ə/ as it does not occur in monosyllabic words, and /ʊ/ and /ɚ/ as no grapheme yields them by default.

24 This list is similar to other lists of vowel GPC rules such as those in Andrews & Scarratt (1998), Seidenberg et al. (1994), and Kessler & Treiman (2001).

To test phonological properties, words in the corpus having the 14 letter strings below were put together (see appendix A for complete list of words):

Table 3.3. Letter strings to test phonological properties

Five Phonological Constraints	Inconsistent		Consistent-Irregular	
	Letter Strings	Examples	Letter Strings	Examples
*V_lax#	-i# -o#	ski /i/ vs. hi /aɪ/ so /o/ vs. to /u/	-a# -e# -u#	pa /ɑ/ he /i/ flu /u/
*æɹ			-ar-	car /ɑɹ/
*V_lax+ɹ			-ir- -yr- -er- -ur-	sir /ɚ/ Byrd /ɚ/ her /ɚ/ fur /ɚ/
*wæ+non_velar	-wa+non_velar -ua+non_velar	want /ɑ/ vs. was /ʌ/ etc. squad /ɑ/ vs. squash /ɔ/		
*wɑɹ	-uar-	quart /ɔɹ/ vs. guard /ɑɹ/	-war-	war /ɔɹ/

In the first constraint, neither word-final <-i, -o> nor word-final <-a, -e, -u> violate *V_lax#, as all the vowels used are tense. These tense vowels are not the regular vowels according to GPC rules (<i, o, a, e, u> are regularly /ɪ, ɑ, æ, ɛ, ʌ/, respectively – as shown in Table 3.2). In the second constraint, the letter string <-ar-> is always irregularly pronounced <ɑɹ> (instead of <æɹ>). Similarly, in the third constraint, the letter strings <-ir-, -yr-, -er-, -ur-> are always irregularly pronounced /ɚ/ (instead of /ɪɹ, ɪɹ, ɛɹ, ʌɹ/). In the fourth constraint, the inconsistency of the letter string <-wa->+non_velar may not be very reliable, owing to large free variation. That is, with the exception of <swam> /æ/ (which has a morphological vowel inflection indicating the past form), all the words having the <-wa-,-wha-> letter strings followed by a non_velar consonant have the vowel /ɑ/, yet this is the second pronunciation in Webster's for <wash> /ɔ/

and for <was, what> /ʌ/ [25]. The letter string <-ua->+non_velar is also inconsistent (/ɑ/ vs. /ɔ/). And, in the fifth constraint, <-uar> is inconsistent having irregular /ɔɹ/ (in <quart, quartz>) and /ɑɹ/ (in <guard> [26]), while <-war-> is consistent-irregular having irregular /ɔɹ/ (e.g. <war>) (the letter <a> regularly represents /æ/).

In order to test orthographic properties, 20 inconsistent bodies [27] and 20 consistent-irregular bodies were selected from the corpus containing 2,719 phonological forms of words with a frequency of 1 or more per million. All 40 bodies are outlined below (see appendix A for complete list of words):

Table 3.4. Bodies to test orthographic properties

Inconsistent			Consistent-Irregular	
Body	Regular	Irregular	Body	Irregular
-ey	they /e/	key /i/	-ourn	mourn /ɔɹ/
-east	least /i/	breast /ɛ/	-ealm	realm /ɛ/
-ound	wound [1] /aʊ/	wound [2] /u/	-ald	bald /ɔ/
-outh	south /aʊ/	youth /u/	-ealt	dealt /ɛ/
-ear	year /ɪɹ/	bear /ɛɹ/	-earl	pearl /ɚ/
-ose	those /o/	whose /u/	-alm	calm /ɑ/
-eight	weight /e/	height /aɪ/	-earch	search /ɚ/
-oad	road /o/	broad /ɔ/	-ign	sign /aɪ/
-eak	speak /i/	break /e/	-eant	meant /ɛ/
-ow	how /aʊ/	know /o/	-ourt	court /ɔɹ/
-own	down /aʊ/	own /o/	-eart	heart /ɑɹ/
-ive	five /aɪ/	give /ɪ/	-ild	child /aɪ/
-ead	read [1] /i/	read [2] /ɛ/	-earn	learn /ɚ/
-oor	poor /ʊɹ/	door /ɔɹ/	-alk	talk /ɔ/
-ome	home /o/	some /ʌ/	-oup	group /u/
-ave	gave /e/	have /æ/	-oung	young /ʌ/
-ind	wind [1] /ɪ/	wind [2] /aɪ/	-igh	high /aɪ/
-eard	beard /ɪɹ/	heard /ɚ/	-ook	look /ʊ/
-all	shall /æ/	small /ɔ/	-ight	right /aɪ/
-eath	wreath /i/	death /ɛ/	-ould	would /ʊ/

25 In Webster's, <swamp, swan, swap, wad, wand, want, wasp, watch, watt> /ɑ/, <swam> /æ/, <wash> /ɔ, ɑ/, and <was, what> /ʌ, ɑ/.
26 The <u> in <guard> is an orthographic marker describing a hard <g> /g/ (Venezky, 1999).
27 All 20 inconsistent bodies have only one “regular” vowel and one irregular “conditioned” vowel. Bodies having two (or more) irregular pronunciations in addition to the regular one are not included (e.g. <-eat>: regular in <beat> /i/, irregular in <great> /e/ and in <sweat, threat> /ɛ/).

The letter strings in Table 3.3 (phonological properties) and bodies in Table 3.4 (orthographic properties) were analyzed for the following four independent variables: (a) the type frequency of a body pronunciation, (b) the token frequency of a body pronunciation, (c) the consistency of a body pronunciation, and (d) the degree of uncertainty H of a body (comprising all of its pronunciations). Below are examples:

Table 3.5. Examples of independent variable values

Properties	Body	Vowel	Words	Type Freq.	Token Freq.	Consis-tency	H
Phono-logical	-i#	/i/	li, mi, si, ski, ti	5	12	.38	.96
		/aɪ/	chi, hi	2	20	.62	
	-u#	/i/	flu	1	2	1	0
Ortho-graphic	-ome	/o/	dome, home, Rome	3	672	.18	.68
		/ʌ/	come, some	2	3,124	.82	
	-ild	/aɪ/	child, mild, wild	3	311	1	0

Word-final <-i#> is inconsistent (irregular /i/ and /aɪ/, regular vowel being /ɪ/), while word-final <-u#> is consistent-irregular (irregular /u/, regular vowel being /ʌ/). The body <-ome> is inconsistent (regular /o/ vs. irregular /ʌ/), while the body <-ild> is consistent-irregular (irregular /aɪ/, regular vowel being /ɪ/). As stated above (section 3.1) and indicated in the highlighted cells above, an inconsistent body has two consistency values and only one H value [28]. Consistency and H are applicable to inconsistent letter strings and bodies, while the type and token frequency of a body are applicable to consistent-irregular letter strings and bodies.

28 The consistency value for a pronunciation – which is a percentage – is calculated from the token frequencies, and the H value is calculated from the consistency values.

The 20 inconsistent bodies in Table 3.4 above have a body-N summed token frequency of at least 200 words per million, a cut-off threshold aimed at ensuring that the inconsistent bodies have a relatively high frequency. For instance, the inconsistent bodies <-eath> and <-alt> both have an H value of .08 while their summed token frequencies are 212 and 80, respectively [29]. Given the 200-words-per-million threshold, the body <-eath> is included in the analysis (Table 3.4) but the body <-alt> is not. The letter strings (Table 3.3 above) and bodies (Table 3.4 above) in the four conditions were used to collect nonwords for analysis, as expounded next.

3.2.3. Data collection and analysis. Nonword LDT data was collected from the English Lexicon Project (ELP) (Balota, Yap, Cortese, Hutchison, Kessler, Loftis, Neely, Nelson, Simpson, & Treiman, 2007) (http://elexicon.wustl.edu). In the LDT task, the focus is almost always on the processing of the words – not the nonwords. Along similar lines, Yap, Sibley, Balota, Ratcliff, & Rueckl (2015) state: "in a lexical decision study, experimenters have little interest in participants' nonword data and typically discard them" (p. 597). Yap et al. (2015), however, show that nonword data in the LDT provide insight into lexical processing and such data may be an area for investigation. The focus in the current analysis is on AE native speakers' accuracy and latency in correctly rejecting nonwords in the LDT.

The LDT data in the ELP comprises 40,481 words and 40,481 nonwords, collected from 816 participants who are AE native speakers. The target nonwords, which are pronounceable, had been created from a master list of words by changing one or two letters in each word, the position of which was

29 The summed token frequencies (per million) are as follows: 3 for <heath, sheath, wreath> /i/, 209 for <breath, death> /ɛ/, 1 for <shalt> /æ/, and 79 for <halt, salt, Walt> /ɔ/.

alternated. Each participant had 3,372 or 3,374 trials, collected during two sessions (first having 2,000 items, second 1,372 or 1,374 items). A participant pressed the “/” key for word, or the “z” key for nonword. For each participants in the LDT, two types of responses (words and nonwords) were removed: (a) those with latency less than 200 ms or more than 3,000 ms, and (b) those with latency 3 SDs below or above the mean for that participant (percentage of outliers in the LDT is 3.57%, *SD* = 3.74). The by-item analysis of nonwords shows that the mean number of observations for the 40,481 nonwords is 28.72 (*SD* = 4.87), the mean latency is 856 (SD 113.75), and the mean accuracy is .88 (*SD* = .13).

The ELP's LDT data of 40,481 nonwords was downloaded, and it contained six types of information: nonwords (monosyllabic and polysyllabic), RTs, Z-scores of RTs, SDs of RTs, number of observations, accuracy (i.e. the accuracy in deciding that the nonwords were not words), and latency. From this downloaded list, nonwords having the letter strings of interest (Table 3.3 above, totaling 14) and bodies of interest (3.4 above, totaling 40) were collected [30]. For each of these 54 letter strings and bodies, the following was analyzed: the number of nonwords having the letter string or body of interest, their sum of observations, their mean number of observations, as well as the mean accuracy and latency, as elaborated on next (see appendix B for more details).

3.3. Results and Discussion

Below is a description of the sample sizes of the collected data in the four conditions (Tables 3.3 and 3.4 above):

30 To increase the number of collected nonwords, bodies having a final “s” and apostrophe plus “s” were also collected.

Table 3.6. Description of collected data sample sizes

Properties	Conditions	# of Bodies of Interest	# of Nonwords in ELP	Sum of Obser-vations in ELP	Mean # of Obser-vations	SD
Phono-logical	Inconsistent	5	58	1,709	29.47	4.65
	Consistent-Irregular	9	284	8,455	29.77	3.37
Ortho-graphic	Inconsistent	20	252	7,094	28.15	4.51
	Consistent-Irregular	20	87	2,636	30.30	3.42

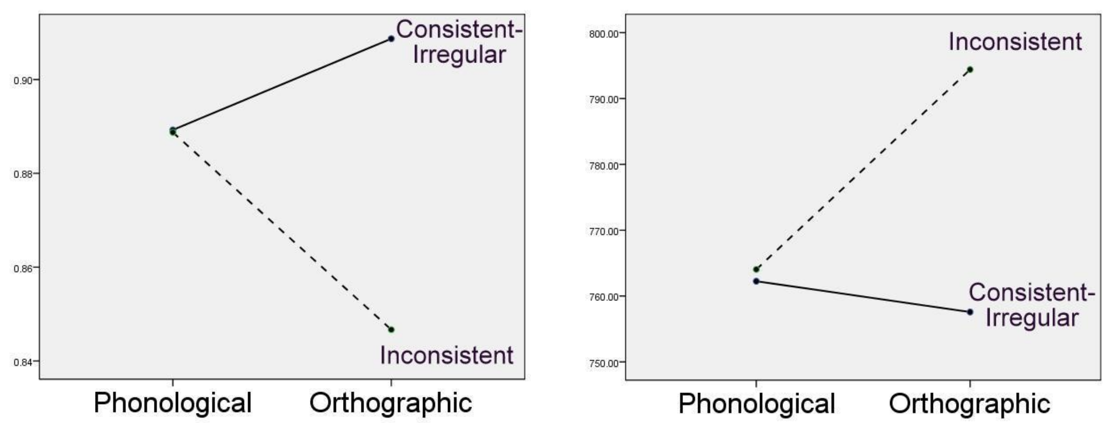
The number of bodies of interest varies in the four conditions (third column), and the number of nonwords collected from the ELP also varies between conditions (fourth column). For instance, there are five inconsistent bodies of interest under phonological properties. The number of nonwords in the ELP having those five bodies (sample size for the phonological inconsistent condition) was 58 and the sum of observations for those 58 nonwords was 1,709. The mean number of observations for those 58 bodies (1,709 / 58) is 29.47 and the SD is 4.65 [31]. As stated above, outliers in the ELP LDT data were removed per participant by the researchers. No further removal of outliers was carried out, which may be additionally justifiable on the grounds that the analyzed data was collected from a very large number of observations. The means and SDs for accuracy and latency in the four conditions are below:

31 The mean number of observations for the 40,481 nonwords in the LDT in the ELP is slightly smaller (*M* = 28.72, *SD* = 4.87).

Table 3.7. Accuracy and latency in the four conditions

Properties	Conditions	Sample Size	Accuracy [32]		Latency [33]	
			Mean	SD	Mean	SD
Phono-logical	Inconsistent	58	.89	.14	764	77
	Consistent-Irregular	284	.89	.10	762	63
Ortho-graphic	Inconsistent	252	.85	.13	794	76
	Consistent-Irregular	87	.91	.09	758	63

The means above are illustrated below, focusing on the effect resulting from the lack of consistency:



Accuracy Latency

Figure 3.1: Marginal means for accuracy and latency

32 These accuracy means are high and the SDs are short, both of which is also true for the 40,481 nonwords in the LDT in the ELP (*M* = .88, *SD* = .13).

33 These latency means are shorter than the mean latency for the 40,481 nonwords in the LDT in the ELP (*M* = 856, *SD* = 113.75), which may be due to the analyzed nonwords being monosyllabic while those in the ELP are of varying syllabic lengths.

The two diagrams above strongly suggest that the effect of the lack of consistency (as a cost) results in less accuracy (left diagram) and longer latency (right diagram) with orthographic properties but not with phonological properties. Two 2x2 analyses of variance (ANOVA) were carried out for respectively accuracy and latency, in both of which the type of property (phonological, orthographic) and consistency (inconsistent, consistent-irregular) are the between-items factors. The very same pattern is obtained in both analyses. With accuracy, there is no main effect of the type of property ($F(1, 677) = 1.11$, $p > .05$), a main effect of consistency ($F(1, 677) = 8.49$, $p < .05$), and an interaction between the type of property and consistency ($F(1, 677) = 8.21$, $p < .05$). With latency, there is no main effect of the type of property ($F(1, 677) = 3.83$, $p > .05$), a main effect of consistency ($F(1, 677) = 8.66$, $p < .05$), and an interaction between the type of property and consistency ($F(1, 677) = 7.13$, $p < .05$).

Additionally, focusing on the *two* conditions under orthographic properties (orthographic–inconsistent, orthographic–consistent-irregular), independent-samples *t* tests were carried out for accuracy and latency, respectively. With accuracy, an independent-samples *t* test *not* assuming homogeneity of variance [34] comparing the accuracy in inconsistent bodies ($M = .85$, $SD = .13$) and consistent-irregular bodies ($M = .91$, $SD = .09$) found the difference to be significant ($t(207.87) = -4.79$, $p < .05$). With latency, similarly, the difference in means between the inconsistent bodies ($M = 794$, $SD = 76$) and the consistent-irregular bodies ($M = 758$, $SD = 63$) is also significant ($t(337) = 4.09$, $p < .05$) [35].

34 A Levene's test of variance had found a violation of the homogeneity of variance ($F(1, 337) = 9.5$, $p < .05$), hence the subsequent independent-samples *t* test not assuming homogeneity of variance and having a smaller degree of freedom (instead of 337).

35 A Levene's test of variance found the samples to satisfy the homogeneity of variance condition ($F(1, 337) = 1.8$, $p > .05$), hence the *t*-test value has the original degree of freedom.

Furthermore, *within* the orthographic–inconsistent condition, the accuracy and latency was calculated for the 20 individual inconsistent bodies (Table 3.4 above). The goal was to test the idea that higher uncertainty H (as a cost) is correlated negatively with accuracy (i.e. more uncertainly H resulting in more nonwords being considered to be words in the LDT, hence more errors) but positively with latency (longer response time). The findings are in line with prediction. Two Pearson's correlations found the following: (a) as predicted, a significant negative correlation between H and accuracy ($r(18) = -.76$, $p < .01$), and (b) as predicted, a positive – though insignificant – correlation between H and latency ($r(18) = .39$, $p > .05$).

The reason for using H instead of consistency is that inconsistent bodies have two consistency values but only one H value (see Table 3.5 above). As shown in Table B.3 in appendix B, with the increase of the consistency of the conditioned vowel, the H value increases, plateaus, then decreases. Conceptually, across the 20 inconsistent bodies in Table B.3 (none having a summed token frequency per million less than 200), the H value here describes a transition from bodies where the consistency of the *regular* vowel is high and decreasing to bodies where the consistency of the *conditioned* vowel is low and increasing – with most uncertainty H occurring halfway through with bodies where the consistency of the two types of vowels are similar (resulting in the longest latency and the most errors).

3.4. Summary of Chapter 3

An attempt was made to address the question of whether vowel accuracy in visual word recognition by AE native speakers is influenced by phonological and/or orthographic factors of English. A hypothesis decoupling the factors influencing this accuracy into phonological and orthographic properties was proposed. The causes underlying vowel accuracy are hypothesized to reflect the type of the processing unit: (a) the vowel and consonant phonemes within a syllable with phonological properties (i.e. restrictions between phonemes), or (b) the vowel and consonant graphemes within the body with orthographic properties (i.e. co-occurrences between graphemes). These two types of influences run counter to the influence of GPC rules.

A corpus was constructed of monosyllabic English words with a frequency of 1 or more per million, from which were taken for further analysis: (a) the letter strings found in five hypothesized phonological constraints (5 inconsistent, 9 consistent-irregular), and (b) the bodies found in irregular words and reflecting orthographic properties (20 inconsistent, 20 consistent-irregular). The effect of the lack of consistency is compared between inconsistent bodies and consistent-irregular bodies, a comparison made for phonological and orthographic properties in a 2x2 experimental design with four conditions. Additionally, for inconsistent bodies, the following were calculated: the consistency of the pronunciation of the conditioned vowel, and the degree of uncertainty H for a body (comprising all of its vowel pronunciations). Nonword LDT data having the letter strings and bodies of interest was collected from the ELP, with accuracy and latency as the dependent variables.

The findings strongly support the phonology-orthography distinction. The effect of the lack of consistency was obtained with orthographic properties (less accuracy and longer latency) but not with phonological properties. Moreover, Pearson's correlations were then calculated for the orthographic inconsistent condition, and they showed the predicted pattern with accuracy (significant negative correlation). Further support for the phonology-orthography distinction may be obtained by its extension to ESL learners using a factorial design, as expounded in the next chapter with Arab ESL learners.

Chapter 4: Arab ESL Learners' Vowel Accuracy

This chapter reports three experiments conducted to examine the underlying source of Arab ESL learners' vowel accuracy in visual word recognition. The goal was to find out whether the distinction between phonological and orthographic properties of English made and supported in the previous chapter may be extended to ESL visual word recognition. The focus is on Arab ESL learners, owing to their poor visual word recognition (section 2.1). This chapter comprises the following: research question and hypothesis, Experiment A (participants, task, experimental design, materials, data analysis, results), Experiment B, Experiment C, a summary of the three experiments, a post hoc analysis of the three experiments, and a discussion.

4.1. Research Question and Hypothesis

There is a two-part research question, which is as follows: Is vowel accuracy in visual word recognition by Arab ESL learners influenced by phonological and/or orthographic factors of English, and does this influence change across proficiency levels? It is hypothesized that: In addition to the influence of GPC rules, vowel accuracy in visual word recognition by Arab ESL learners is influenced by two distinct sources: (a) phonological properties of English: phonological constraints, reflecting the strength of a constraint and remaining constant across proficiency levels; and, (b) orthographic properties of English: reflected in the consistency and regularity effects, both increasing across proficiency levels.

As in the previous chapter (analysis of AE native speakers' nonword LDT data from the ELP), two types of vowels are compared: the default regular vowel (according to GPC rules) and the conditioned vowel (found in irregular English words violating GPC rules). This conditioning of vowels is caused by the neighboring consonant phoneme(s) in case of phonological properties, or by the neighboring consonant grapheme(s) in case of orthographic properties. For Arab ESL learners, it is above hypothesized that the use of the conditioned vowel will be reflected differently with phonological and orthographic properties, with changes (or lack thereof) across proficiency levels.

4.2. Experiment A: Phonological Constraints

The goal in this experiment is to determine whether the distinction between strong and weak phonological constraints is supported with Arab ESL learners, tested across proficiency levels. It is predicted that the use of the conditioned vowel will be high with strong phonological constraints but low with weak ones, a pattern unchanged across proficiency levels.

4.2.1. Participants. The participants were 44 Arab ESL learners (speaking the Saudi dialect) at EPI at USC, Columbia who were enrolled in the reading/vocabulary class. Based on their scores on a reading proficiency placement test taken after the data had been collected, the participants were put into two proficiency groups: high proficiency (n = 22), and low proficiency (n = 22). The participants' length of studying English at EPI varied from 2 to 24 months, yet there was no significant correlation between the length of studying English at EPI and the reading proficiency placement test scores (low proficiency $r(20) = -.27$, $p > .05$; high proficiency $r(20) = -.08$, $p > .05$; combined $r(42) = .17$, $p > .05$).

4.2.2. Task. The nonword naming task was used, constructed and run using the software program e-Prime. The procedure was as follows: (a) The plus sign is presented as a fixation point for 2,000 ms on a monitor; (b) A nonword replaces the plus sign; (c) A participant reads the nonword into two microphones, one for recording the audio response and the other for detecting the response onset; (d) If a response is detected within 2,000 ms, the latency is displayed (in blue print) for 2,000 ms; otherwise, the message “Too Slow” is displayed (in red print) for 2,000 ms. The participants were given instructions (verbal and on the monitor) to respond as fast and as accurately as possible, and the emphasis on speed was encouraged by the feedback on every trial (the displayed latency in blue when a response is detected, the message “Too Slow” in red otherwise).

There was a practice session (20 items), during which the researcher was present. The participants were alone during the trial session (120 test items and 40 fillers). All the 160 items were seen by each participant in the two proficiency groups. Of the 120 test items, 40 items were for Experiment A, 40 for Experiment B, and 40 for Experiment C. The items were evenly distributed in two blocks, separated by a break. The items were randomized within a block and counterbalanced in the two blocks. A participation session took less than 25 minutes. The participants received no compensation (monetary or class credit). Data collection took place during summer 2014.

4.2.3. Experimental design. There are eight conditions obtained by manipulating three factors: within-subjects strength of constraint (strong vs. weak) x within-subjects applicability of constraint (applies vs. doesn't apply) x between-subjects proficiency (low vs. high), as outlined below:

Table 4.1. Experiment A (constraints): Conditions

<table>
<tr><th></th><th></th><th>Low Proficiency</th><th>High Proficiency</th></tr>
<tr><td rowspan="2">Strong</td><td>Constraint Applies</td><td>strong / experimental / low proficiency</td><td>strong / experimental / high proficiency</td></tr>
<tr><td>Constraint doesn't Apply</td><td>strong / control / low proficiency</td><td>strong / control / high proficiency</td></tr>
<tr><td rowspan="2">Weak</td><td>Constraint Applies</td><td>weak / experimental / low proficiency</td><td>weak / experimental / high proficiency</td></tr>
<tr><td>Constraint doesn't Apply</td><td>weak / control / low proficiency</td><td>weak / control / high proficiency</td></tr>
</table>

4.2.4. Materials. The four letter strings below were tested (each letter string having 10 nonwords, for a total of 40 test items per participant):

Table 4.2. Experiment A (constraints): Tested letter strings

<table>
<tr><th rowspan="2">Strength</th><th rowspan="2">Applicability</th><th rowspan="2">Letter String</th><th colspan="2">Vowel</th><th rowspan="2">Examples</th></tr>
<tr><th>Regular</th><th>Conditioned</th></tr>
<tr><td rowspan="2">Strong</td><td>Constraint Applies</td><td>-i#</td><td rowspan="2">/ɪ/</td><td>/i/
/aɪ/</td><td>ski
hi</td></tr>
<tr><td>Constraint doesn't Apply</td><td>-it</td><td>n/a</td><td>hit</td></tr>
<tr><td rowspan="2">Weak</td><td>Constraint Applies</td><td>-wa+non_velar</td><td rowspan="2">/æ/</td><td>/ɑ/
/ʌ/
/ɔ/
/æ/</td><td>want
was
wash
swam</td></tr>
<tr><td>Constraint doesn't Apply</td><td>-wa+velar</td><td>n/a</td><td>wax</td></tr>
</table>

Five phonological constraints are recognized in the previous chapter (section 3.1). The letter strings in the table above represent the first one (hypothesized to be strong): *V_lax# (no lax vowel syllable-finally), and the fourth one (hypothesized to be weak): *wæ+non_velar (no /æ/ between an onset /w/ and a non-velar coda). The second, third, and fifth phonological constraints (*æɹ, *V_lax+ɹ, and *wɑɹ, respectively) were left out of Experiment A in order to maintain symmetry between the three experiments (A, B, and C).

There are similarities between the test items: <t> is added to an open syllable in the first constraint, and non-velar codas are compared with velar ones in the fourth one. There are 10 test items for each letter string, and the same is true for the bodies in Experiments B and C. The following considerations were taken into account when creating the nonwords in all three experiments: (a) None of the nonwords are similar to (sound like) Arabic words, (b) All the nonwords have a two-letter onset representing two consonant sounds [36], (c) Nonwords with a word embedded in them were avoided or kept to a minimum [37], and (d) An attempt was made to avoid or keep to a minimum nonwords homophonic with English words regularly or irregularly (e.g. for the inconsistent body <-ead>, <fread> is regularly homophonic with <freed> and is irregularly homophonic with <Fred> by non-regular analogy with irregular words such as <bread, dread, spread, thread>) [38].

4.2.5. Data analysis. Mistrials were removed, comprising: data entries with response time (RT) less than 300 ms or larger than 1,500 ms, those with no recorded audio response, those with no detection of RT, and those with the

36 The following two-letter onsets were not used, as they represent a single consonant sound: <ch, ph, sh, th, wh> for respectively /ʧ, f, ʃ, θ ~ ð, w/.
37 When this could not be avoided, preference was given to embedded words having a low frequency (e.g. <drook, prook> with the LF word <rook> vs. <clook> with the HF word <look>).
38 When this could not be avoided, preference was given to nonwords homophonic with LF rather than HF words. For example, in the first phonological constraint *V_lax#, preference was given to <sti> (homophonic with the LF word <sty>) over <tri> (homophonic with the HF words <tree> and <try>).

wrong RT (e.g. a click precedes the response). Each audio response was analyzed by the researcher for the vowel used and coded as: (a) the default regular vowel, (b) the conditioned vowel, or (c) some other vowel. The focus is on the proportion of the conditioned vowel, entered as a score from 0 to 10 (as there are 10 nonwords per body in all three experiments). As each participant was presented with all the conditions in the three experiments, the statistical test used was the repeated measure (RM) ANOVA. The between-subjects factor was proficiency, while the within-subjects variable was the relevant independent variable. As there are only two levels of the RM factor in all the analyses, sphericity is always met (Mauchly's sphericity test) and the F-ratios are valid.

4.2.6. Results. The proportion of the conditioned vowel is reported in the means, the SDs of the means, and the RTs below:

Table 4.3. Experiment A (constraints): Proportion of conditioned vowel

Strength	Applicability	Letter String	Low Proficiency			High Proficiency		
			Mean	(SD)	RT	Mean	(SD)	RT
Strong	Constraint Applies	-i#	.53	(.31)	686	.74	(.23)	710
	Constraint doesn't Apply	-it	.32	(.28)	730	.25	(.30)	719
Weak	Constraint Applies	-wa+non_velar	.03	(.06)	683	.03	(.09)	733
	Constraint doesn't Apply	-wa+velar	.02	(.06)	717	.01	(.05)	878

There are three 2x2 RM ANOVA analyses. First, with the strong constraint, a 2x2 RM ANOVA (within-subjects applicability: applies vs. doesn't apply; between-subjects proficiency: low vs. high) found a main effect of the strong constraint ($F(1, 42) = 41.06$, $p < .05$), no main effect of proficiency ($F(1, 42) = 1.21$, $p > .05$), and an interaction with proficiency ($F(1, 42) = 6.40$, $p < .05$) (i.e. increase with <-i#>, decrease with <-it>). Conversely, with the weak constraint, a 2x2 RM ANOVA (within-subjects applicability: applies vs. doesn't apply; between-subjects proficiency: low vs. high) found no main effect of the weak constraint ($F(1, 42) = 1.95$, $p > .05$), no main effect of proficiency ($F(1, 42) = .07$, ns), and no interaction with proficiency ($F(1, 42) = .70$, ns). And, third, the RM scores for each participant were recoded (score with applies minus score with doesn't apply), thus collapsing the applicability factor (applies vs. doesn't apply) under the strength factor (strong vs. weak) and rendering a 2x2 design. A 2x2 RM ANOVA (within-subjects: strong vs. weak; between-subjects proficiency: low vs. high) found the following: a main effect of the strength of a constraint ($F(1, 42) = 35.68$, $p < .05$), a main effect of proficiency ($F(1, 42) = 7.28$, $p < .05$), and an interaction between the strength of a constraint and proficiency ($F(1, 42) = 5.37$, $p < .05$). The findings above support the distinction between strong and weak phonological constraints. That is, the strong constraint items resulted in higher proportion of the conditioned vowel when a constraint applies compared to the items when it does not, and the former proportion increased with proficiency while the latter decreased. On the other hand, with the weak constraint, the proportion of the conditioned vowel was very low with both applicability levels, neither of which changed with proficiency.

4.3. Experiment B: Orthographic Consistency

In line with the literature (section 2.3.4.7 above), there is higher accuracy of the conditioned vowel when its consistency is higher. The goal here is to test whether the orthographic consistency effect (higher proportion of the conditioned vowel with higher consistency) is obtained with Arab ESL learners.

4.3.1. Participants and task. Same as in Experiment A.

4.3.2. Experimental design. There are four conditions, obtained by manipulating two factors: within-subjects consistency (high vs. low) x between-subjects proficiency (low vs. high), as outlined below:

Table 4.4. Experiment B (consistency): Conditions

		Low Proficiency	High Proficiency
Consistency	High	high consistency / low proficiency	high consistency / high proficiency
	Low	low consistency / low proficiency	low consistency / high proficiency

4.3.3. Materials. The four bodies below were tested (each body having 10 nonwords, for a total of 40 test items per participant):

Table 4.5. Experiment B (consistency): Tested bodies

Consis-tency	Body	Vowel		Type Freq.	Token Freq.	Consis-tency [39]	Examples
		Reg-ular	Cond-itioned				
High	-ind	/ɪ/	/aɪ/	8	1,621	.90	wind /ɪ/ vs. find
	-ead	/i/	/ɛ/	12	1,334	.65	read /i/ vs. head
Low	-int	/ɪ/	/aɪ/	7	44	.05	print vs. pint
	-eaf	/i/	/ɛ/	2	42	.31	leaf vs. deaf

There are similarities between the bodies (<-ind, -ead> vs. <-int, -eaf>). The low-consistency items acted as a control for the experimental high-consistency items.

4.3.4. Data analysis. Same as in Experiment A.

4.3.5. Results. Below are the means for the proportion of the conditioned vowel, the SDs of the means, and the RTs:

39 The consistency values are for the conditioned vowel. The consistency of the regular vowel is the remaining percentage, e.g. .10 for <-ind> with /ɪ/.

Table 4.6. Experiment B (consistency): Proportion of conditioned vowel

Consistency	Body & (Consistency)	Low Proficiency			High Proficiency		
		Mean	(SD)	RT	Mean	(SD)	RT
High	-ind (/aɪ/ .90) -ead (/ɛ/ .65)	.25	(.27)	770	.22	(.29)	740
Low	-int (/aɪ/ .05) -eaf (/ɛ/ .31)	.19	(.22)	753	.16	(.27)	709

A 2x2 RM ANOVA (within-subjects consistency: high vs. low; between-subjects proficiency: low vs. high) found the following: a main effect of consistency ($F(1, 42) = 16.09$, $p < .05$), no main effect of proficiency ($F(1, 42) = .25$, ns), and no interaction with proficiency ($F(1, 42) = .02$, ns). These findings suggest that the higher the consistency of a conditioned vowel in English words, the more likely it is to be used when pronouncing nonwords by Arab ESL learners of both low and high proficiency. This use, measured in the comparison between experimental high-consistency vs. control low-consistency bodies, stays constant across proficiency levels (a difference of 6 between the respective means). Hence, the effect of the lack of constancy is obtained, and it does not change with proficiency.

4.4. Experiment C: Orthographic Regularity

As discussed above (section 2.3.5), Andrews & Scarratt (1998) found the use of the conditioned vowel to be higher with consistent-irregular bodies (the two NRA groups) than with consistent-regular bodies. The goal here is to test whether the orthographic regularity effect (higher proportion of the conditioned vowel with consistent-irregular bodies than consistent-regular bodies) is obtained with Arab ESL learners.

4.4.1. Participants and task. Same as in Experiment A.

4.4.2. Experimental design. There are four conditions, obtained by manipulating two factors: within-subjects regularity (consistent-irregular vs. consistent-regular) x between-subjects proficiency (low vs. high), as outlined below:

Table 4.7. Experiment C (regularity): Conditions

		Low Proficiency	High Proficiency
Regularity	Consistent-Irregular	consistent-irregular / low proficiency	consistent-irregular / high proficiency
	Consistent-Regular	consistent-regular / low proficiency	consistent-regular / high proficiency

4.4.3. Materials. The four bodies below were tested (each body having 10 nonwords, for a total of 40 test items per participant):

Table 4.8. Experiment C (regularity): Tested bodies

Regularity	Body	Vowel		Type Freq.	Token Freq.	Examples
		Regular	Conditioned			
Consistent-Irregular	-ild	/ɪ/	/aɪ/	3	311	child
	-ook	/u/	/ʊ/	8	1,714	look
Consistent-Regular	-ilt	/ɪ/	n/a	4	10	tilt
	-oom	/u/		9	465	room

The tested bodies are similar (i.e. <-ild, -ook> vs. <-ilt, -oom>). The consistent-regular items acted as a control for the experimental consistent-irregular items.

4.4.4. Data analysis. Same as in Experiment A.

4.4.5. Results. The means for the proportion of the conditioned vowel, the SDs of the means, and the RTs are below:

Table 4.9. Experiment C (regularity): Proportion of conditioned vowel

Regularity	Body	Low Proficiency			High Proficiency		
		Mean	(SD)	RT	Mean	(SD)	RT
Consistent-Irregular	-ild (/aɪ/) -ook (/ʊ/)	.23	(.27)	760	.19	(.27)	700
Consistent-Regular	-ilt (/ɪ/) -oom (/u/)	.19	(.27)	694	.15	(.29)	765

A 2x2 RM ANOVA (within-subjects regularity: consistent-irregular vs. consistent-regular; between-subjects proficiency: low vs. high) found the following: no main effect of regularity ($F(1, 42) = 2.11$, $p > .05$), no main effect of proficiency ($F(1, 42) = .83$, ns), and no interaction with proficiency ($F(1, 42) = .03$, ns). Although there is some numerical evidence for the regularity effect (higher proportion of the conditioned vowel with consistent-irregular than consistent-regular bodies, with both low and high proficiency groups), this evidence does not reach significance. Thus, the effect of the lack of regularity is not obtained.

4.5. Summary of the three Experiments

As stated above, audio responses for each participant were recoded into one of three categories: regular vowel, conditioned vowel, or another vowel. The analyses above (sections 4.2, 4.3, 4.4) focused on the proportion of the conditioned vowel only [40]. These analyses support the distinction between strong and weak phonological constraints (Experiment A), and they provide support for the orthographic consistency effect (Experiment B) but not the orthographic regularity effect (Experiment C).

40 Similarly, Treiman et al., (2003) (section 2.4.3) classified responses from AE native speakers in a nonword naming task into three categories: typical (or regular) vowel, critical (or conditioned) vowel, or another vowel. They, also similarly, focused their analysis on the critical (conditioned) vowel.

The obtained findings are interesting in many respects, namely the *early emergence* of the studied influences, their *robustness*, and their *change* across proficiency levels. First, the early emergence of the studied influences suggests that Arab ESL learners have a high sensitivity to English phonological and orthographic properties early on. This early emergence reflects the specific properties of English being studied. That is, the early emergence occurred with the strong but not the weak constraint under phonological properties (Experiment A), and it was more pronounced with experimental than control items under orthographic properties (high vs. low consistency in Experiment B, and consistent-irregular vs. consistent-regular in Experiment C).

Second, the robustness of the influences is reflected differently with phonological and orthographic properties: under phonological properties (Experiment A), the robustness is very high with the strong constraint and practically non-existent with the weak one; while under orthographic properties, it is higher with the consistency effect (Experiment B) than the regularity effect (Experiment C). Interestingly, obtaining a more robust effect of consistency than regularity with Arab ESL learners is in line with the literature on AE native speakers' visual word recognition. For example, Cortese & Simpson (2000) and Jared (2002) found that consistency accounted for more word naming variance than regularity. In fact, Cortese & Simpson (2000) state that while many studies have demonstrated the consistency effect, “not one study involving the reading of words has shown a stronger effect of regularity than of consistency” (p. 1273). Thus, both the consistency and regularity effects reflect properties of English orthography, and their robustness is similarly obtained with AE native speakers and Arab ESL learners.

And, third, the changes of these influences across proficiency levels are the reverse of those predicted: increase (instead of constancy) with the strong constraint (Experiment A), and constancy (instead of increase) with the consistency and regularity effects (Experiments B and C) (i.e. numerical decrease that was not statistically significant). The hypothesized direction of change was justified on the assumption that the increase of the amount of print exposure and word familiarity would result in an increase of the consistency and regularity effects (both under orthographic properties) but would not have an influence on phonological properties.

Explaining these changes requires taking into account the influence of GPC rules yielding the default regular vowel (Andrews & Scarratt, 1998, section 2.3.5). In the post hoc analysis below, there is a comparison between the different influences: GPC rules (regular vowel), phonological constraints (conditioned vowel), orthographic consistency (conditioned vowel), and orthographic regularity (conditioned vowel). The post hoc analysis addresses issues such as the interpretation of the increase of the proportion of the conditioned vowel with the strong constraint, and the question of why the consistency and regularity effects stayed constant instead of increasing.

4.6. Post Hoc Analysis of the three Experiments

This post hoc analysis compares the proportion of three vowel types: regular, conditioned, and others. As shown below, the post hoc analysis suggests that the influence of the strong constraint is greater than that of GPC rules (increase of the former despite the latter), and it suggests that the regularity and consistency effects stayed constant owing to the increasing influence of GPC rules (increase of the regular vowel at the expense of the conditioned vowel).

Regarding the tested bodies in Experiments B and C (Tables 4.5 and 4.8), this post hoc analysis is limited to bodies showing the largest differences in means. All the means are in the proportions (i.e. percentages, excluded from which are mistrials) below:

Table 4.10. Overall proportions of vowels in the three experiments

Exp-eriment	Body	Low Proficiency			High Proficiency		
		Reg-ular	Cond-itioned	Others	Reg-ular	Cond-itioned	Others
A	-i#	.04	.53	.40	.03	.74	.21
	-it	.35	.32	.32	.59	.25	.14
	-wa+non_velar	.52	.03	.43	.64	.03	.31
	-wa+velar	.53	.02	.42	.68	.01	.28
B	-ind	.43	.37	.18	.57	.32	.10
	-int	.55	.25	.18	.70	.20	.10
	-ead	.36	.13	.49	.60	.12	.26
	-eaf	.36	.13	.49	.57	.13	.28
C	-ild	.43	.35	.20	.54	.27	.17
	-ilt	.49	.28	.19	.64	.23	.12
	-ook	.11	.10	.76	.18	.11	.69
	-oom	.29	.11	.56	.42	.08	.49

Across the board, the proportion of vowels other than the regular and conditioned ones produced by Arab ESL learners is large [41] and it decreased with higher levels of proficiency. This decrease is concomitant with: (a) an increase in the use of the conditioned vowel only with <-i#> (two highlighted cells), or (b) an increase in the use of the regular vowel with all remaining bodies (highlighted). That is, Arab ESL learners seem to fine-tune their visual word recognition by increasingly choosing vowels that are present in English words.

41 Treiman et al. (2003) (section 2.4.3) found that less than 3% of all AE native speakers' responses were for other vowels.

Concerning the bodies in Experiment B, most of the difference in means was obtained with the pair <-ind, -int> (conditioned vowel /aɪ/) rather than the pair <-ead, -eaf> (conditioned vowel /ɛ/), as shown below:

Table 4.11. Experiment B (consistency): Proportion of conditioned vowel #2

Consistency	Body & (Consistency)	Low Proficiency			High Proficiency		
		Mean	(SD)	RT	Mean	(SD)	RT
High	-ind (/aɪ/ .90)	.37	(.30)	789	.32	(.32)	756
Low	-int (/ɪ/ .05)	.25	(.25)	721	.20	(.30)	737
High	-ead (/aɪ/ .65)	.13	(.18)	718	.12	(.21)	698
Low	-eaf (/ɛ/ .31)	.13	(.16)	811	.13	(.24)	666

Focusing on the <-ind, -int> pair, a 2x2 RM ANOVA (within-subjects consistency: high vs. low; between-subjects proficiency: low vs. high) found the following: a main effect of consistency ($F(1, 42) = 22.52$, $p < .05$), no main effect of proficiency ($F(1, 42) = .32$, ns), and no interaction with proficiency ($F(1, 42) = .01$, ns). This main effect of consistency obtained with the <-ind, -int> pair is more robust than the one obtained for all four bodies in the analysis above (section 4.3.5) ($F(1, 42) = 16.09$, $p < .05$). The observation that the consistency effect was obtained with the pair <-ind, -int> rather than the pair <-ead, -eaf> is in line with expectation. That is, the difference in consistency value is large in the first pair (consistency of /aɪ/ being very high at .90 with <-ind> but very low at .05 with <-int>) but small in the second pair (consistency of /ɛ/ is not very high at .65 with <-ead> and not very low at .31 with <-eaf>).

Similarly, regarding the bodies in Experiment C, most of the difference in means was obtained with the pair (<-ild, -ilt>) but not the pair (<-ook, -oom>), as shown below:

Table 4.12. Experiment C (regularity): Proportion of conditioned vowel #2

Body (and Vowel)	Type Freq.	Token Freq.	Low Proficiency			High Proficiency		
			Mean	(SD)	RT	Mean	(SD)	RT
-ild (/aɪ/)	3	311	.35	(.30)	756	.27	(.33)	747
-ilt (/ɪ/)	4	10	.28	(.26)	730	.23	(.33)	760
-ook (/ʊ/)	8	1,714	.10	(.15)	772	.11	(.17)	587
-oom (/u/)	9	465	.11	(.24)	602	.08	(.22)	780

Focusing on the <-ild, -ilt> pair, a 2x2 RM ANOVA (within-subjects regularity: consistent-irregular vs. consistent-regular; between-subjects proficiency: low vs. high) found the following: a main effect of regularity ($F(1, 42) = 4.37$, $p < .05$), no main effect of proficiency ($F(1, 42) = .61$, ns), and no interaction with proficiency ($F(1, 42) = .23$, ns). In the analysis of Experiment C (section 4.4.5) above, no main effect of regularity was obtained with all four bodies (consistent-irregular <-ild, -ook> vs. consistent-regular <-ilt, -oom>) ($F(1, 42) = 2.11$, $p > .05$). The fact that the consistent-irregular body <-ook> has a high type frequency (8) and a high token frequency (1,714) should have resulted in a high proportion of the conditioned vowel /ʊ/. There is no clear explanation as to why this outcome did not happen [42].

The changes in the means of the vowel used are illustrated below for four of the 12 bodies in Table 4.10 above: strong constraint (<-i#>) (Experiment A), weak constraint (<-wa>+non_velar) (Experiment A), consistency effect (<-ind>) (Experiment B), and regularity effect (<-ild>) (Experiment C):

42 The vowel /ʊ/ is an Arabic allophone (Tables 2.3 and 2.4 above), so negative phonological transfer is not the cause of the avoidance of AE /ʊ/. Hypothetically, Arab ESL learners may have an avoidance of using a short vowel when the vowel grapheme suggests a long vowel (as the two vowel letters <oo> in <-ook> do, regularly yielding the tense/long vowel /u/).

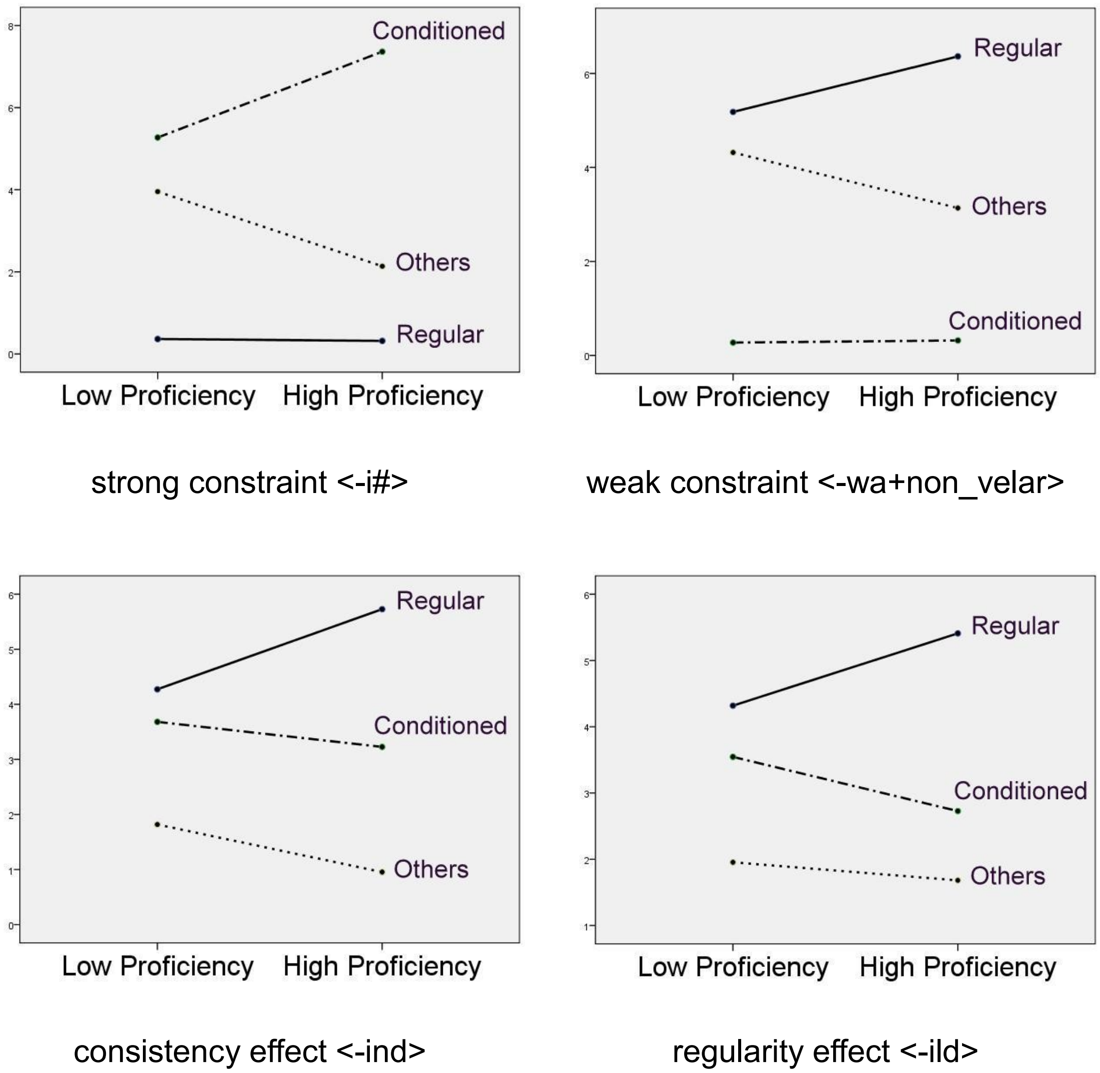


Figure 4.1. Marginal means of vowels used

In all four diagrams, there is a decrease in the use of “others” (i.e. vowels other than the regular vowel and the conditioned vowel). With the strong constraint <-i#>, the use of the conditioned vowel is high and increases while the use of the regular one is very low and remains constant. The very reverse is true with the weak constraint <-wa+non_velar>. Three RM ANOVA tests found the difference in means between the two letter strings <-i#> and <-wa+non_velar> to be respectively: significant with the regular vowel ($F(1, 42) = 99.10$, $p < .05$), significant with the conditioned vowel ($F(1, 42) = 193.20$, $p < .05$), but not significant with others ($F(1, 42) = 2.15$, $p > .05$). These findings further support the distinction between strong and weak phonological constraints in terms of the regular and conditioned vowels having the reverse pattern, while other vowels having the same decreasing pattern (obtained across the board).

On the other hand, the pattern with <-ind> (consistency effect) and <-ild> (regularity effect) is identical: an increase in the regular vowel and a decrease in the conditioned vowel and others. Three RM ANOVA tests found the difference in means between the bodies <-ind> and <-ild> to be not significant across the board (regular: $F(1, 42) = .19$, ns; conditioned: $F(1, 42) = 2.12$, $p > .05$; others: $F(1, 42) = 3.28$, $p > .05$). These findings support the recognition of the consistency and regularity effects as being similar in that both fall under orthographic properties (lack of consistency and regularity, respectively).

Moreover, the phonology-orthography distinction is supported in the comparison between the strong constraint <-i#> (under phonological properties) and the consistency effect with <-ind> (under orthographic properties), the latter chosen over the regularity effect with <-ilt> on account of its being more robust. Three RM ANOVA tests found the difference in means between the letter string <-i#> and the body <-ind> to be significant across the board (regular: $F(1, 42) = 83.72$, $p < .05$, conditioned: $F(1, 42) = 31.45$, $p < .05$, others: $F(1, 42) = 22.72$, $p < .05$). Thus, support for the phonology-orthography distinction is obtained with the conditioned vowel, the regular vowel, and other vowels.

All the findings above support the distinctions made in the hypothesis but not the changes across proficiency levels made in it. The post hoc analysis explains the changes in three respects: (a) The increase (instead of constancy) in the use of the conditioned vowel with the strong constraint may be an indication that the influence of the strong constraint is greater than that of GPC rules, (b) The constancy (instead of increase) in the use of the conditioned vowel with the consistency and regularity effects may be a result of the increasing influence of GPC rules, yielding more use of the regular vowel at the expense of the conditioned one, and (c) The use of other vowels decreased across the board, suggesting that Arab ESL learners fine-tune their visual word recognition by increasingly using only vowels that are present in English words.

4.7. Discussion

The following hypothesis was made above (section 4.1). In addition to the influence of GPC rules, vowel accuracy in visual word recognition by Arab ESL learners is influenced by two distinct sources: (a) phonological properties of English: phonological constraints, reflecting the strength of a constraint and remaining constant across proficiency levels; and, (b) orthographic properties of English: reflected in the consistency and regularity effects, both increasing across proficiency levels. Based on the analysis of the proportion of the conditioned vowel, a strong support was found for the distinction between strong and weak phonological constraints (Experiment A), and the consistency effect was obtained (Experiment B) while the regularity effect was not (Experiment C).

Focusing on tested bodies in Experiments B and C with large differences in means, a post hoc analysis found a stronger consistency effect (<-ind, -int>) and also a regularity effect (<-ild, -ilt>). Furthermore, taking into account the three types of vowels (regular, conditioned, others), the post hoc analysis found the following: (a) further support for the distinction between strong and weak phonological constraints, (b) no difference between the consistency and regularity effects – both falling under orthographic properties, and (c) support for the phonology-orthography distinction. Additionally, the post hoc analysis explains the changes in the proportions of the conditioned vowels in terms of the overall increase of the regular vowel (strong constraint excepted), an overall increase which renders the use of the conditioned vowel constant and the use of other vowels decreasing.

Given the focus on visual word recognition accuracy in the current study, latency is reported but not analyzed [43]. Not undertaking an analysis of latency may be justifiable in the literature. For instance, comparing nine tasks in which there is emphasis on either phonological or orthographic processing by AE native speakers, Hagiliassis et al. (2006) regard “orthographic processing as a distinct psychological construct, dissociable from phonological processing, at least when accuracy data are considered” (p. 258). The researchers add: “if researchers intend to evaluate orthographic or phonological processing as directly and as separately as possible, then an accuracy-based performance measure should be adopted” (p. 260). Furthermore, it may also be the case that L2 learners' accuracy in L2 visual word recognition is more valid than their latency. For instance, Wang & Koda (2007), in a word naming study with Korean and Chinese ESL learners, obtained an effect of frequency (higher accuracy with HF than LF words) and an effect of regularity (higher accuracy with regular than irregular words), but they found that latency was not relevant owing to the low accuracy with LF words. The researchers state: “L2 learners shift their efforts toward accuracy more than speed in word processing, because they have limited resources to allocate in processing L2 materials” (p. 216).

43 All the test items were controlled for onset length, onset consistency, and onset regularity (see section 4.2.4 above).

4.8. Summary of Chapter 4

An attempt was made to extend to Arab ESL learners the distinction between the influence of phonological and orthographic properties of English on accuracy in visual word recognition. The goal was to determine whether this distinction is obtained and to find out its pattern of change across proficiency levels. Nonword naming data was collected from 44 Saudi EPI participants, who were split into two groups: low proficiency (n = 22) and high proficiency (n = 22).

Focusing on the proportion of the conditioned vowel, the distinction between strong and weak phonological constraints was supported (Experiment A), and the orthographic consistency effect was obtained (Experiment B) while the orthographic regularity effect was not (Experiment C).

In a post hoc analysis looking into the proportion of regular, conditioned, and other vowels across proficiency levels, the following was found: (a) further support for the strong-weak distinction under phonological properties, (b) the similarity between the consistency and regularity effects, both falling under orthographic properties, and (c) support for the phonological-orthographic distinction. Additionally, the post hoc analysis explains changes that are contrary to predictions: (a) the conditioned vowel increasing (instead of staying constant) with the strong constraint – suggesting its strength, (b) the conditioned vowel remaining constant (instead of increasing) with the consistency and regularity effects – owing to the increasing influence of GPC rules (i.e. higher use of the regular vowel, at the expense of the conditioned one), and (c) an overall decrease in the use of other vowels, suggesting only vowels used in English are being increasingly used. These findings explicate the different causes underlying Arab ESL learners' choice of vowel in visual word recognition.

Chapter 5: General Discussion, Future Directions, and Conclusion

5.1. Summary and Discussion

Arab ESL learners have poor performance in their ESL visual word recognition, in comparison with non-Arab ESL learners (Fender, 2003; 2008; Hayes-Harb, 2006; Ryan & Meara, 1991). This poor performance has been attributed to the transfer of the L1 visual word recognition strategy of focusing on consonant letters (Hayes-Harb, 2006; Ryan & Meara, 1991) and to their poor L2 spelling knowledge (Fender, 2003; 2008), the latter explanation having more empirical support. These explanations, however, do not consider the factors influencing visual word recognition accuracy by AE native speakers – the area investigated in the current study.

In the literature, two factors influencing AE native speakers' visual word recognition accuracy have been extensively studied and compared, focusing on the effects resulting from the lack of regularity and/or consistency: GPC rules, and non-regular analogy (e.g. Andrews & Scarratt, 1998; Cortese & Simpson, 2000; Glushko, 1979; Jared, 2002). Non-regular analogy is an orthography-based factor whereby an inconsistent body results in longer latency and less accuracy in visual word recognition (e.g. <-ave>, irregular in <have> but regular in <cave, save, wave>) (Glushko, 1979). Inconsistency is also orthography-based in that it arises when children learn to read an inconsistent orthography (e.g. English) but not a consistent one (e.g. German) (Goswami et al., 2005).

The main contribution made in the current study is the distinction between the influence on visual word recognition accuracy stemming from phonological and orthographic properties of English, both set against the backdrop of the influence of GPC rules. In line with the hypothesized phonology-orthography distinction, Rayner et al. (2001) state that: "*print exposure* accounts for variance in word recognition and spelling that is not accounted for by *phonological processing* in adults (A.E. Cunningham, Stanovich, & Wilson, 1990; Stanovich & West, 1989) and children (A.E. Cunningham & Stanovich, 1991)" (p. 40, emphasis added). Somewhat similarly, Seidenberg et al. (1994) make the following suggestion: "future research will have to address how these orthographic and phonological representations develop. In reality, phonological representations are determined by constraints on possible segments imposed by articulatory and perceptual capacities and by characteristics of the language" (p. 1189).

In chapter 3, it is hypothesized that, in addition to the influence of GPC rules, vowel accuracy in visual word recognition stems from two distinct sources: phonological properties (phonological constraints), and orthographic properties (orthographic consistency and regularity). The vowel sound is influenced by the neighboring consonant <u>sound(s)</u> in the former but the neighboring consonant <u>letter(s)</u> in the latter. In both cases, there is a violation of vowel GPC rules as a vowel other than the default regular one is used. The analysis of AE native speakers' nonword LDT data in the ELP (comparing inconsistent bodies with consistent-irregular bodies) provides a strong support for the phonology-orthography distinction, as the expected pattern in accuracy and latency is obtained with orthographic properties but not phonological properties.

In chapter 4, this phonology-orthography distinction was tested with Arab ESL learners. It is hypothesized that, in addition to the influence of GPC rules, their vowel accuracy in visual word recognition is influenced by two distinct sources: (a) phonological properties of English: phonological constraints, reflecting the strength of a constraint and remaining constant across proficiency levels, and (b) orthographic properties of English: reflected in the consistency and regularity effects, both increasing across proficiency levels. Based on the analysis of the proportion of the conditioned vowel, the distinction between strong and weak phonological constraints was supported, and the consistency and regularity effects were obtained – the former more robust, which is in line with the literature. The obtained patterns of change across proficiency levels in the use of the conditioned vowel were somewhat different from those predicted. That is, the use: (a) is high and increases (instead of staying constant) with the strong constraint, (b) is low and remains low (as predicted) with the weak one, and (c) is mediocre and stays constant (instead of increasing) with the orthographic consistency and regularity effects.

The constancy in the use of the conditioned vowel may be explained in terms of the increasing influence of GPC rules yielding the regular vowel. Taking into account changes across proficiency levels in the use of the regular, conditioned, and other vowels, the following is found: (a) There is an across-the-board decrease in the use of vowels other than the regular and conditioned ones (i.e. those not found in English words), and (b) There is an overall increase in the use of the regular vowel, the strong phonological constraint excepted (see Figure 4.1 above). These two findings strongly support the theoretical position that ESL learners progressively move away from using vowels not used in English words, mostly in favor of the regular vowels yielded by GPC rules. The only exception to this overall increase in the use of the regular vowel is with the strong phonological constraint *V_lax#, but not the weak constraint *wæ+non_velar. These observations support the distinction between strong and weak constraints, both falling under phonological properties.

Moreover, with the consistency and regularity effects, both falling under orthographic properties, the same pattern is observed: increased use of the regular vowel (influence of GPC rules), which offsets and renders constant the use of the conditioned vowel (influence of non-regular analogy, an orthographic factor). That is, with the exception of the strong phonological constraint (*V_lax#), the influence of GPC rules is dominant and is counterbalanced by the influence of non-regular analogy. This last finding is in line with the literature on AE native speakers' visual word recognition. For instance, Andrews & Scarratt (1998) show that, in nonword naming, readers rely heavily on GPC rules (yielding the regular vowel), a tendency that is counterbalanced when the body being processed is inconsistent or consistent-irregular – both cases resulting in orthographic non-regular analogy (yielding the conditioned vowel) (section 2.3.5 and Table 2.7).

Overall, the findings above provide explanation for the influence consonants have on vowels, tested in nonword naming. As stated above (section 2.4.3 and Table 2.9), Treiman et al. (2003) found that, using nonword naming, there is a large inexplicable variation in the use of the conditioned (critical) vowel. The proposed distinctions attempt to explain variation in the use of the conditioned (critical) vowel in terms of phonological properties of English (strong versus weak phonological constraints), as distinct from orthographic properties of English (consistency and regularity effects).

Importantly, the obtained findings do not challenge the theoretical position that Arab ESL learners' poor performance in visual word recognition (Fender 2003; Hayes-Harb, 2006; Ryan & Meara, 1991) is due to their poor *spelling knowledge* (Fender 2008) (section 2.1.3). Instead, the obtained findings shed light on the influences underlying the development of not the spelling knowledge per se [44] but rather the knowledge of correspondences between orthographic forms and phonological representations (GPC rules, violated in instances of irregularity at the word level and/or inconsistency at the body level), both types of knowledge falling under the mental lexicon (Fender, 2008). Fender (2008) recognizes the connection between Arab ESL learners' encoding skills using a spelling test and their decoding visual word recognition skills tested in tasks such as the LDT (Fender, 2003) as well as other tasks (Hayes-Harb, 2006) (section 2.1.3). As stated above (section 2.3.1), there is evidence obtained with AE native speakers showing that the same mental lexicon is used during visual word recognition (decoding) and during spelling out words (encoding) (Burt & Tate, 2002; Ehri, 1997; Holmes & Carruthers, 1998), and both decoding and encoding skills improve with greater exposure to and experience with written words (Rayner et al., 2001).

Furthermore, two types of knowledge are widely recognized: explicit and implicit (see R. Ellis, 1994, for a review), and an L2 is learned explicitly and implicitly (N. Ellis, 1999). The difference between the two type of knowledge (spelling knowledge vs. knowledge of correspondences between orthographic forms and phonological representations) can be understood in terms of the explicit-implicit distinction: encoding reflects explicit knowledge (demonstrable

44 Saigh & Schmidt (2012) look into those causes, and (Fender, 2008) discusses some possible explanations.

during spelling out words, from mental representations to written output), while decoding reflects implicit knowledge (during visual word recognition, from visual input to mental representations).

More broadly, the obtained findings in the current study fit with the cognitive theory of L2 acquisition focusing on *mental representations* and *processes* (N. Ellis, 1999; 2006; 2013). The current study looks into the emergence and development of *mental representations*, tapped into during the visual word recognition *process.* The obtained findings strongly suggest that Arab ESL learners' visual word recognition (and in turn their mental representations) is influenced by the L2 visual input, specifically the frequency of the input items and their regularity and consistency. Along these lines, N. Ellis (1999) states: "*Frequency* of chunk in the input, and *regularity* and *consistency* of associative mappings with other representational domains, results in the emergence of effectively localist, categorical units, especially, but by no means exclusively, at lexical grain." (p. 11, emphasis added) [45]. The variables of regularity and consistency are manipulated in the current study (chapters 3 and 4), and the summed token frequency of inconsistent bodies (consistency and degree of uncertainty H) is also taken into account (chapter 3). Moreover, N. Ellis (2013) states that type and token frequency differ in their influence: type frequency strengthens the "representational schema", while token frequency strengthens "irregular forms". Arguably, in the case of visual word recognition, "representational schemas" describes the correspondences between graphemes

45 N. Ellis (1999) asserts that the emergentist aspect of the cognitive theory of L2 account is simulated in connectionism, as "connectionist models can extract the regularities in each of these domains of language and then operate in a rule-like (but not rule-governed) way" (p. 10). A connectionist model calculates the strength of these correspondences (alternately describable as rules) between graphemes and phonemes, taking into account their violation (with inconsistent bodies).

and phonemes formularized in GPC rules, and “irregular forms” describe irregular words violating GPC rules. These two types of influences are also taken into account in the current study.

To sum up, Arab ESL learners' visual word recognition shows the overall increasing influence of GPC rules, as well as the influence of distinct phonological properties (strong vs. weak constraints) and orthographic properties (consistency and regularity effects, the former – in line with the literature – more robust). These findings fit within the cognitive theory of L2 acquisition, as characteristics of the L2 visual input such as frequency, regularity, and consistency show up in the analysis of the collected nonword naming data. The current study set out to test the influence of properties of English on Arab ESL learners' accuracy in visual word recognition, rather than their ability to demonstrate spelling knowledge – the mental lexicon being used in both skills. Although their poor *explicit* spelling knowledge is the main cause of their poor performance in visual word recognition, their visual word recognition is nevertheless influenced by exposure to the L2 and results in increasing *implicit* knowledge of the correspondences between English graphemes and phonemes as well as the irregularities and inconsistencies therein.

5.2. Future Directions

As these phonological and orthographic factors do not arise from the L1 (i.e. L1 transfer) but rather from the L2, they should – in theory – influence ESL learners with different L1s in a similar fashion. Along similar lines, in their study of visual word recognition by Korean and Chinese ESL learners (tested in word naming), Wang & Koda (2007) obtained an effect of frequency and regularity with both Korean and Chinese ESL learners. The researchers state that: “properties of the L2 writing system affect L2 processing similarly across learners irrespective of the L1 background” (p. 202).

Whether the findings obtained here can be replicated with non-Arab ESL learners may be an area of investigation for future research. For instance, the following distinctions may be tested: (a) strong versus weak phonological constraints, (b) consistency effect (with inconsistent bodies) versus regularity effect (with consistent-irregular bodies), and (c) strong constraint (falling under phonological properties) versus consistency effect (falling under orthographic properties). Using nonword naming, these distinctions may be tested in the use of: (a) the regular vowel (influence of GPC rules), (b) the conditioned vowel (owing to phonological constraints that are strong or weak, on the one hand, or non-regular analogy reflecting the lack of consistency and/or regularity, on the other), or (c) some other vowel.

5.3. Conclusion

The current study investigated Arab ESL learners' vowel accuracy in ESL visual word recognition in terms of the factors influencing this accuracy with AE native speakers – specifically properties of English phonology and English orthography, respectively. This phonology-orthography distinction was strongly supported in the analysis of AE native speakers' nonword LDT data from the ELP (chapter 3). Further support was obtained with Arab ESL learners, in the analysis of their pronunciation of vowels using the nonword naming task (chapter 4). There is support for the distinction between strong and weak phonological constraints, both of which exhibited a pattern different from that obtained with the orthographic consistency effect and the orthographic regularity effect (the former more robust). It is argued that this phonology-orthography distinction may be relevant to the study of ESL visual word recognition accuracy by ESL learners in general, insofar as the distinction reflects an L2 (rather than an L1) factor. The approach taken and obtained findings are compatible with the cognitive theory of L2 acquisition, given the focus on characteristics of the input (frequency, regularity, consistency). Further research may be able to shed more light on the studied areas, and the current study may be replicated with non-Arab ESL learners.

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Appendix A: Words having Bodies of Interest (Chapter 3)

Table A.1. Phonological properties: Inconsistent

Cons-traint	Letter String	Vowel	Words
1st	-i#	/i/	li mi si ski ti
		/aɪ/	chi hi
	-o#	/o/	fro go ho Jo lo no oh o' Po pro quo so yo
		/u/	do to who
4th	-wa+ non_velar	/ɑ/	swamp swan swap wad wand want wasp watch watt
		/ʌ/	was what
		/ɔ/	wash
		/æ/	swam
	-ua+ non_velar	/ɑ/	squad squat, Guam, Juan
		/ɔ/	squash
5th	-uar-	/ɔɹ/	quart quartz
		/ɑɹ/	guard

Table A.2. Phonological properties: Consistent-Irregular

Cons-traint	Letter String	Vowel	Words
1st	-a#	/ɑ/	ah ha la ma pa
	-e#	/i/	be he me she the we ye
		/e/	eh [46]
	-u#	/u/	flu
2nd	-ar-	/ɑɹ/	ark bark Clark dark mark park shark spark stark, art cart chart dart hart mart part smart start, bar car czar far jar scar star tar tsar, bard card hard lard yard, arm charm farm harm, garp harp sharp, Carl Karl snarl, arch march starch, harsh marsh, barn yarn, Lars mars, arc, Carr, garb, Marx, scarf
3rd	-ir-	/ɚ/	fir sir stir, dirt shirt skirt, girl swirl whirl, bird third, first thirst, dirk kirk, birth, birch, firm
	-yr-		Byrd
	-er-		er fer her per yer, germ sperm term, fern stern Vern, herb verb, clerk jerk, Bert, herd, Herr, perch
	-ur-		blur fur spur ur, curt hurt Kurt spurt, burn churn turn, surf turf, burr purr, church lurch, burnt, burst, curb, curl
5th	-war-	/ɔɹ/	dwarf swarm war ward warm warn warp wart wharf

46 Rounding results in the vowel /e/ in <eh> (token frequency = 3) having a 0 consistency, while /i/ in <be, he, me, she, the, we, ye> (token frequency = 87,567) having a consistency of 1. Hence, the letter string <e#> is consistent-irregular.

Table A.3. Orthographic properties: Inconsistent

Body	Vowel	Words
-ey	/e/	grey hey prey they
	/i/	key
-east	/i/	beast east feast least yeast
	/ɛ/	breast
-ound	/aʊ/	bound found ground hound mound pound round sound wound[1]
	/u/	wound[2]
-outh	/aʊ/	mouth south
	/u/	youth
-ear	/ɪɹ/	clear dear ear fear gear hear near rear smear spear tear[1] year
	/ɛɹ/	bear pear swear tear[2] wear
-ose	/o/	close chose dose hose nose pose prose rose those
	/u/	lose whose
-eight	/e/	eight freight weight
	/aɪ/	height
-oad	/o/	load road toad
	/ɔ/	broad
-eak	/i/	beak bleak creak freak leak peak sneak speak squeak streak weak
	/e/	break steak
-ow	/aʊ/	bow[1] brow cow how now ow plow row[1] sow[1] vow wow
	/o/	blow bow[2] crow flow glow grow know low mow row[2] show slow snow sow[2] throw tow
-own	/aʊ/	brown clown crown down drown frown gown town
	/o/	blown flown grown known own shown thrown
-ive	/ɪ/	dive drive five hive live[1] strive thrive
	/aɪ/	give live[2]
-ead	/i/	bead lead[1] mead plead read[1]
	/ɛ/	bread dead dread head lead[2] read[2] spread thread tread

-oor	/ʊɹ/ /ɔɹ/	moor poor door floor
-ome	/o/ /ʌ/	dome home Rome come some
-ave	/e/ /æ/	brave cave Dave gave grave save shave slave wave have
-ind	/ɪ/ /aɪ/	wind [1] bind blind find grind hind kind mind wind [2]
-eard	/ɪɹ/ /ɚ/	beard heard
-all	/æ/ /ɔ/	shall all ball call fall hall mall small stall tall wall
-eath	/i/ /ɛ/	heath sheath wreath breath death

Table A.4. Orthographic properties: Consistent-Irregular

Body	Vowel	Words
-ourn	/ɔɹ/	mourn
-ealm	/ɛ/	realm
-ald	/ɔ/	bald
-ealt	/ɛ/	dealt
-earl	/ɚ/	earl pearl
-alm	/ɑ/	calm palm
-earch	/ɚ/	search
-ign	/aɪ/	sign
-eant	/ɛ/	meant
-ourt	/ɔɹ/	court
-eart	/ɑɹ/	heart
-ild	/aɪ/	child mild wild
-earn	/ɚ/	earn learn
-alk	/ɔ/	chalk stalk talk walk
-oup	/u/	coup group soup
-oung	/ʌ/	young
-igh	/aɪ/	high nigh sigh thigh
-ook	/ʊ/	book brook cook crook hook look shook took
-ight	/aɪ/	blight bright Dwight fight flight fright knight light might night plight right sight slight tight Wright
-ould	/ʊ/	could should would

Appendix B: Bodies and Data for Analysis (Chapter 3)

Table B.1. Phonological properties: Inconsistent

Con-straint	Body	Vowels	Variables		ELP Data			
					# of Non-words	# of Re-sponses	Accuracy	
			Consistency	H			Mean	SD
1st	-i#	/ɪ/	0	.96	6	186	.9482	.0518
		/i/	.38					
		/aɪ/	.62					
	-o#	/ɑ/	0	.61	10	307	.9359	.1180
		/o/	.15					
		/u/	.85					
4th	-wa+ non_velar	/æ/	0	.32	15	372	.7489	.1739
		/ɑ/	.06					
		/ʌ/	.94					
		/ɔ/	0					
	-ua+ non_velar	/æ/	0	.81	19	592	.9292	.0632
		/ɑ/	.75					
		/ɔ/	.25					
5th	-uar-	/æɹ/	0	.63	8	252	.9511	.0357
		/ɔɹ/	.16					
		/ɑɹ/	.84					

Note: The consistency values highlighted in the 4th column are for the regular vowel.

Table B.2. Phonological properties: Consistent-Irregular

Con-straint	Body	Vowels		Variables		ELP Data			
						# of Non-words	# of Re-sponses	Accuracy	
		Re-gular	Cond-itioned	Type Freq.	Token Freq.			Mean	SD
1^{st}	-a#	/æ/	/ɑ/	5	65	8	248	.9303	.0586
	-e#	/ɛ/	/i/	8	87,570	10	308	.9371	.0778
	-u#	/ʌ/	/u/	1	2	2	66	.9857	.0202
2^{nd}	-ar-	/æɹ/	/ɑɹ/	56	3,335	101	2994	.8831	.0849
3^{rd}	-ir-	/ɪɹ/	/ɚ/	18	2,085	50	1495	.8932	.0927
	-er-	/ɛɹ/		19	2,999	48	1455	.9025	.1014
	-ur-	/ʌɹ/		21	584	54	1571	.8683	.1132
	-yr-	/ɪɹ/		1	2	3	87	.8970	.1274
5^{th}	-war-	/æɹ/	/ɔɹ/	9	519	8	231	.8764	.0929

Note: By definition with consistent-irregular bodies, the regular vowel is never used in English words. The type and token frequencies (5^{th} and 6^{th} columns above) are for the conditioned vowel.

Table B.3. Orthographic properties: Inconsistent

Body	Vowels	Variables		ELP Data			
				# of Non-words	# of Re-sponses	Accuracy	
		Consistency	H			Mean	SD
-ey	/e/	.99	.08	6	185	.9204	.0354
	/i/	.01					
-east	/i/	.98	.14	5	156	.9280	.0524
	/ɛ/	.02					
-ound	/aʊ/	.98	.14	14	424	.9126	.0720
	/u/	.02					
-outh	/aʊ/	.93	.37	8	237	.8886	.0648
	/u/	.07					
-ear	/ɪɹ/	.86	.59	16	447	.8377	.1421
	/ɛɹ/	.14					
-ose	/o/	.85	.61	14	400	.8638	.0899
	/u/	.15					
-eight	/e/	.82	.68	6	184	.9100	.0903
	/aɪ/	.18					
-oad	/o/	.80	.72	11	309	.8416	.0876
	/ɔ/	.20					
-eak	/i/	.79	.89	17	454	.8034	.1708
	/e/	.31					
-ow	/aʊ/	.67	.98	29	767	.7970	.1504
	/o/	.43					
-own	/aʊ/	.56	.99	20	493	.7426	.1806
	/o/	.44					
-ive	/aɪ/	.48	1	14	390	.8390	.1379
	/ɪ/	.52					
-ead	/i/	.35	.93	19	518	.8195	.1448
	/ɛ/	.65					
-oor	/ʊɹ/	.27	.84	10	288	.8648	.0803
	/ɔɹ/	.73					

-ome	/o/ /ʌ/	.12 .82	.68	12	355	.8918	.1367
-ave	/e/ /æ/	.11 .89	.50	12	358	.9038	.0772
-ind	/ɪ/ /aɪ/	.10 .90	.47	15	430	.8745	.0970
-eard	/ɪɹ/ /ɚ/	.04 .96	.25	2	61	.9246	.0182
-all	/æ/ /ɔ/	.03 .97	.19	15	425	.8506	.1126
-eath	/i/ /ɛ/	.01 .99	.08	7	213	.8914	.0562

Note: The consistency values highlighted in the 3rd column are for the conditioned vowel. With the increase of the consistency of the conditioned vowel, the H values increase, plateau, then decrease (see section 3.3).

Table B.4. Orthographic properties: Consistent-Irregular

Body	Vowels		Variables		ELP Data			
					# of Non-words	# of Re-sponses	Accuracy	
	Re-gular	Cond-itioned	Type Freq.	Token Freq.			Mean	SD
-ourn	/aʊ/	/oɹ/	1	1	1	29	.9063	n/a
-ealm	/i/	/ɛ/	1	6	2	61	.8971	.0624
-ald	/æ/	/ɔ/	1	7	5	149	.8919	.0565
-ealt	/i/	/ɛ/	1	9	2	50	.7848	.2614
-earl	/i/	/ɚ/	2	21	4	125	.9457	.0553
-alm	/æ/	/ɑ/	2	49	6	181	.8869	.1029
-earch	/i/	/ɚ/	1	67	1	30	.8571	n/a
-ign	/ɪ/	/aɪ/	1	101	1	30	.9091	n/a
-eant	/i/	/ɛ/	1	102	1	29	.8529	n/a
-ourt	/aʊ/	/ɔɹ/	1	118	2	63	.9839	.0228
-eart	/i/	/ɑɹ/	1	170	2	65	.9853	.0208
-ild	/ɪ/	/aɪ/	3	311	5	158	.9344	.0582
-earn	/i/	/ɚ/	2	321	2	60	.8973	.0568
-alk	/æ/	/ɔ/	4	371	8	231	.8772	.0513
-oup	/aʊ/	/u/	3	381	8	245	.9210	.0717
-oung	/aʊ/	/ʌ/	1	429	2	62	.9412	.0832
-igh	/ɪ/	/aɪ/	4	498	6	194	.9648	.0234
-ook	/u/	/ʊ/	8	1,714	11	320	.8787	.0846
-ight	/ɪ/	/aɪ/	16	2,693	15	456	.9082	.1534
-ould	/aʊ/	/ʊ/	3	4,883	3	98	.9513	.0342

Note: By definition with consistent-irregular bodies, the regular vowel is never used in English words. The type and token frequencies (4th and 5th columns above) are for the conditioned vowel.

Appendix C: Bodies in Test Items (Chapter 4)

Table C.1. Experiment A (phonological constraints)

Letter String	Vowel	Words
-i#	/i/	li mi si ski ti
	/aɪ/	chi hi
-it	/i/	bit fit git hit it kit knit lit pit quit sit slit spit split wit
-wa+ non_velar	/ɑ/	swamp swan swap wad wand want wasp watch watt
	/ʌ/	was what
	/ɔ/	wash
	/æ/	swam
-wa+velar	/æ/	wag Wang wax

Table C.2. Experiment B (orthographic consistency): Inconsistent

Body	Vowel	Words
-ind	/ɪ/	wind [1]
	/aɪ/	bind blind find grind hind kind mind wind [2]
-int	/ɪ/	flint glint hint mint print splint
	/aɪ/	pint
-ead	/i/	bead lead [1] mead plead read [1]
	/ɛ/	bread dead dread head lead [2] read [2] spread thread tread
-eaf	/i/	leaf
	/ɛ/	deaf

Table C.3. Experiment C (orthographic regularity): Consistent-Irregular

Body	Vowel	Words
-ild	/aɪ/	child mild wild
-ilt	/ɪ/	gilt silt tilt wilt
-ook	/ʊ/	book brook cook crook hook look shook took
-oom	/u/	bloom boom broom doom gloom groom loom room zoom

Appendix D: Test Items, Fillers, and Practice Items (Chapter 4)

Table D.1. Test items in Experiment A: Phonological constraints

<table>
<tr><th rowspan="3">Block</th><th colspan="2">Strong Phonological Constraint</th><th colspan="2">Weak Phonological Constraint</th></tr>
<tr><th>Experimental:
-i#</th><th>Control:
-it/-id</th><th>Experimental:
-wa+non_velar</th><th>Control:
-wa+velar</th></tr>
<tr><th>regular /ɪ/
conditioned /i, aɪ/</th><th>regular /ɪ/
conditioned n/a</th><th>regular /æ/
conditioned /ɑ, ʌ, ɔ/</th><th>regular /æ/
conditioned /æ/</th></tr>
<tr><td>1</td><td>bli
dwi
gli
pri
smi</td><td>clit
drit
plit
stit
swit</td><td>swaft
swand
swant
swapt
swask</td><td>kwang
swack
swax
twact
twank</td></tr>
<tr><td>2</td><td>cli
dri
pli
sti
swi</td><td>blit
dwit
glit
prit
smit</td><td>twaft
twand
twant
twapt
twask</td><td>kwank
swac
swact
twack
twax</td></tr>
</table>

Table D.2. Test items in Experiment B: Orthographic consistency

Block	High Consistency		Low Consistency	
	-ind	-ead	-int	-eaf
	regular /ɪ/ conditioned /aɪ/	regular /i/ conditioned /ɛ/	regular /ɪ/ conditioned /aɪ/	regular /i/ conditioned /ɛ/
1	brind dwind plind skind smind	clead dwead pread slead snead	crint drint slint snint twint	creaf gleaf skeaf smeaf sweaf
2	crind drind slind snind twind	cread glead skead smead swead	brint dwint plint skint smint	cleaf dweaf preaf sleaf sneaf

Table D.3. Test items in Experiment C: Orthographic regularity

Block	Consistent-Irregular		Consistent-Regular	
	-ild	-ook	-ilt	-oom
	regular /ɪ/ conditioned /aɪ/	regular /u/ conditioned /ʊ/	regular /ɪ/ conditioned n/a	regular /u/ conditioned n/a
1	brild drild prild snild twild	clook prook slook stook twook	crilt dwilt frilt swilt trilt	droom ploom skoom swoom troom
2	crild dwild frild swild trild	drook plook skook swook trook	brilt drilt prilt snilt twilt	cloom proom sloom stoom twoom

Table D.4. Fillers in the three experiments

Block 1		Block 2	
baft /æ/ bew /ju/ cym /ɪ/ dibe /aɪ/ doist /ɔɪ/ floap /o/ fripe /aɪ/ fump /ʌ/ grawl /ɔ/ hane /e/	hetch /ɛ/ klig /ɪ/ leme /i/ loun /aʊ/ pob /ɑ/ prack /æ/ saunch /ɔ/ skrout /aʊ/ spotch /ɑ/ voy /ɔɪ/	crief /i/ daist /e/ flesk /ɛ/ frisp /ɪ/ glat /æ/ gope /o/ groost /u/ hife /aɪ/ meech /i/ mube /ju/	pooth /u/ skop /ɑ/ smout /aʊ/ snile /aɪ/ spuck /ʌ/ spoint /ɔɪ/ trawn /ɔ/ troid /ɔɪ/ vam /æ/ zow /aʊ/

Table D.5. Practice items

broon /u/	flain /e/	skawl /ɔ/	stog /ɑ/
crid /ɪ/	gleep /i/	sloud /aʊ/	trabe /e/
doint /ɔɪ/	glute /u/	smine /aɪ/	troke /o/
druck /ʌ/	naul /ɔ/	smop /ɑ/	vene /i/
fept /ɛ/	prab /æ/	snat /æ/	voal /o/